

PCT

REQUEST

The undersigned requests that the present international application be processed according to the Patent Cooperation Treaty.

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International Application No.

International Filing Date

Name of receiving Office and "PCT International Application"

Applicant's or agent's file reference
(if desired) (12 characters maximum) 57.0551 WO PCT

Box No. I TITLE OF INVENTION	
ELECTRICAL TREATMENT FOR OIL BASED DRILLING OR COMPLETION FLUIDS	
Box No. II APPLICANT <input type="checkbox"/> This person is also inventor	
Name and address: (Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)	Telephone No.
M-I SWACO 5950 North Course Drive Houston, TX 77072 United States of America	Facsimile No.
	Teleprinter No.
	Applicant's registration No. with the Office
State (that is, country) of nationality: United States of America	State (that is, country) of residence: United States of America
This person is applicant for the purposes of: <input type="checkbox"/> all designated States <input checked="" type="checkbox"/> all designated States except the United States of America <input type="checkbox"/> the United States of America only <input type="checkbox"/> the States indicated in the Supplemental Box	
Box No. III FURTHER APPLICANT(S) AND/OR (FURTHER) INVENTOR(S)	
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CARRIER, Michelle Bridget 3 Ainsworth Court Cambridge CB1 2PA United Kingdom	<input type="checkbox"/> applicant only <input checked="" type="checkbox"/> applicant and inventor <input type="checkbox"/> inventor only (If this check-box is marked, do not fill in below.)
	Applicant's registration No. with the Office
State (that is, country) of nationality: Australia	State (that is, country) of residence: United Kingdom
This person is applicant for the purposes of: <input type="checkbox"/> all designated States <input type="checkbox"/> all designated States except the United States of America <input checked="" type="checkbox"/> the United States of America only <input type="checkbox"/> the States indicated in the Supplemental Box	
<input checked="" type="checkbox"/> Further applicants and/or (further) inventors are indicated on a continuation sheet.	
Box No. IV AGENT OR COMMON REPRESENTATIVE; OR ADDRESS FOR CORRESPONDENCE	
The person identified below is hereby/has been appointed to act on behalf of the applicant(s) before the competent International Authorities as: <input checked="" type="checkbox"/> agent <input type="checkbox"/> common representative	
Name and address: (Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)	Telephone No.
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Continuation of Box No. III FURTHER APPLICANT(S) AND/OR (FURTHER) INVENTOR(S)

If none of the following sub-boxes is used, this sheet should not be included in the request.

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- ☐ applicant only
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United Kingdom

This person is applicant for the purposes of:

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Name and address: (Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)

This person is:

- ☐ applicant only
☐ applicant and inventor
☐ inventor only (If this check-box is marked, do not fill in below.)

Applicant's registration No. with the Office

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This person is:

- ☐ applicant only
☐ applicant and inventor
☐ inventor only (If this check-box is marked, do not fill in below.)

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This person is:

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Box No. V DESIGNATIONS

The filing of this request constitutes under Rule 4.9(a), the designation of all Contracting States bound by the PCT on the international filing date, for the grant of every kind of protection available and, where applicable, for the grant of both regional and national patents.

However,

- ☐ DE Germany is not designated for any kind of national protection
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(The check-boxes above may be used to exclude (irrevocably) the designations concerned in order to avoid the ceasing of the effect, under the national law, of an earlier national application from which priority is claimed. See the Notes to Box No. V as to the consequences of such national law provisions in these and certain other States.)

Box No. VI PRIORITY CLAIM

The priority of the following earlier application(s) is hereby claimed:

Filing date of earlier application (day/month/year)	Number of earlier application	Where earlier application is:		
		national application: country or Member of WTO	regional application:* regional Office	international application: receiving Office
item (1) 12 August 2003 (12.08.03)	0318840.6	GB		
item (2)				
item (3)				

☐ Further priority claims are indicated in the Supplemental Box.

The receiving Office is requested to prepare and transmit to the International Bureau a certified copy of the earlier application(s) (only if the earlier application was filed with the Office which for the purposes of this international application is the receiving Office) identified above as:

☒ all items ☐ item (1) ☐ item (2) ☐ item (3) ☐ other, see Supplemental Box

* Where the earlier application is an ARIPO application, indicate at least one country party to the Paris Convention for the Protection of Industrial Property or one Member of the World Trade Organization for which that earlier application was filed (Rule 4.10(b)(ii)):

Box No. VII INTERNATIONAL SEARCHING AUTHORITY

Choice of International Searching Authority (ISA) (if two or more International Searching Authorities are competent to carry out the international search, indicate the Authority chosen; the two-letter code may be used):

ISA / EPO

Request to use results of earlier search; reference to that search (if an earlier search has been carried out by or requested from the International Searching Authority):

Date (day/month/year) Number Country (or regional Office)

Box No. VIII DECLARATIONS

The following declarations are contained in Boxes Nos. VIII (i) to (v) (mark the applicable check-boxes below and indicate in the right column the number of each type of declaration):

- | | | | |
|---|--|---|--|
| <input type="checkbox"/> Box No. VIII (i) | Declaration as to the identity of the inventor | : | |
| <input type="checkbox"/> Box No. VIII (ii) | Declaration as to the applicant's entitlement, as at the international filing date, to apply for and be granted a patent | : | |
| <input type="checkbox"/> Box No. VIII (iii) | Declaration as to the applicant's entitlement, as at the international filing date, to claim the priority of the earlier application | : | |
| <input type="checkbox"/> Box No. VIII (iv) | Declaration of inventorship (only for the purposes of the designation of the United States of America) | : | |
| <input type="checkbox"/> Box No. VIII (v) | Declaration as to non-prejudicial disclosures or exceptions to lack of novelty | : | |

Number of
declarations

Box No. IX CHECK LIST; LANGUAGE OF FILING

<p>This international application contains:</p> <p>(a) in paper form, the following number of sheets:</p> <p>request (including declaration sheets) : 4</p> <p>description (excluding sequence listing and/or tables related thereto) : 19</p> <p>claims : 2</p> <p>abstract : 1</p> <p>drawings : 5</p> <p>Sub-total number of sheets : 31</p> <p>sequence listing : :</p> <p>tables related thereto : :</p> <p><i>(for both, actual number of sheets if filed in paper form, whether or not also filed in computer readable form; see (c) below)</i></p> <p>Total number of sheets : 31</p> <p>(b) <input type="checkbox"/> only in computer readable form (Section 801(a)(i))</p> <p>(i) <input type="checkbox"/> sequence listing</p> <p>(ii) <input type="checkbox"/> tables related thereto</p> <p>(c) <input type="checkbox"/> also in computer readable form (Section 801(a)(ii))</p> <p>(i) <input type="checkbox"/> sequence listing</p> <p>(ii) <input type="checkbox"/> tables related thereto</p> <p>Type and number of carriers (diskette, CD-ROM, CD-R or other) on which are contained the</p> <p><input type="checkbox"/> sequence listing:</p> <p><input type="checkbox"/> tables related thereto:</p> <p><i>(additional copies to be indicated under items 9(ii) and/or 10(ii), in right column)</i></p>	<p>This international application is accompanied by the following item(s) (mark the applicable check-boxes below and indicate in right column the number of each item):</p> <p>1. <input checked="" type="checkbox"/> fee calculation sheet : 1</p> <p>2. <input type="checkbox"/> original separate power of attorney : :</p> <p>3. <input type="checkbox"/> original general power of attorney : :</p> <p>4. <input type="checkbox"/> copy of general power of attorney; reference number, if any: : :</p> <p>5. <input type="checkbox"/> statement explaining lack of signature : :</p> <p>6. <input type="checkbox"/> priority document(s) identified in Box No. VI as item(s): : :</p> <p>7. <input type="checkbox"/> translation of international application into (language): : :</p> <p>8. <input type="checkbox"/> separate indications concerning deposited microorganism or other biological material : :</p> <p>9. <input type="checkbox"/> sequence listing in computer readable form (indicate type and number of carriers)</p> <p>(i) <input type="checkbox"/> copy submitted for the purposes of international search under Rule 13ter only (and not as part of the international application) : :</p> <p>(ii) <input type="checkbox"/> (only where check-box (b)(i) or (c)(i) is marked in left column) additional copies including, where applicable, the copy for the purposes of international search under Rule 13ter : :</p> <p>(iii) <input type="checkbox"/> together with relevant statement as to the identity of the copy or copies with the sequence listing mentioned in left column : :</p> <p>10. <input type="checkbox"/> tables in computer readable form related to sequence listing (indicate type and number of carriers)</p> <p>(i) <input type="checkbox"/> copy submitted for the purposes of international search under Section 802(b-quater) only (and not as part of the international application) : :</p> <p>(ii) <input type="checkbox"/> (only where check-box (b)(ii) or (c)(ii) is marked in left column) additional copies including, where applicable, the copy for the purposes of international search under Section 802(b-quater) : :</p> <p>(iii) <input type="checkbox"/> together with relevant statement as to the identity of the copy or copies with the tables mentioned in left column : :</p> <p>11. <input checked="" type="checkbox"/> other (specify): Form 23/77 : 1</p>	<p>Number of items</p>
<p>Figure of the drawings which should accompany the abstract: 8</p>	<p>Language of filing of the international application: English</p>	

Box No. X SIGNATURE OF APPLICANT, AGENT OR COMMON REPRESENTATIVE

Next to each signature, indicate the name of the person signing and the capacity in which the person signs (if such capacity is not obvious from reading the request).



Akram K. Mirza

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<p>1. Date of actual receipt of the purported international application:</p> <p>3. Corrected date of actual receipt due to later but timely received papers or drawings completing the purported international application:</p> <p>4. Date of timely receipt of the required corrections under PCT Article 11(2):</p> <p>5. International Searching Authority (if two or more are competent): ISA /</p>	<p>2. Drawings:</p> <p><input type="checkbox"/> received:</p> <p><input type="checkbox"/> not received:</p> <p>6. <input type="checkbox"/> Transmittal of search copy delayed until search fee is paid</p>

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FEE CALCULATION SHEET

Annex to the Request

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International Application No.

Applicant's or agent's
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57.0551 WO PCT

Date stamp of the receiving Office

Applicant

M-I SWACO

CALCULATION OF PRESCRIBED FEES

1. TRANSMITTAL FEE 55.00 [T]

2. SEARCH FEE 1078.00 [S]

International search to be carried out by

(If two or more International Searching Authorities are competent to carry out the international search, indicate the name of the Authority which is chosen to carry out the international search.)

3. INTERNATIONAL FILING FEE

Where items (b) and/or (c) of Box No. IX apply, enter Sub-total number of sheets } 31
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[i1] first 30 sheets 628.00 [i1]

[i2] 1 x 7 = 7.00 [i2]
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4. FEE FOR PRIORITY DOCUMENT (if applicable) 22.00 [P]

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Date: 30 June 2004

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Signature:

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10/517332

DT09 Rec'd PCT/PTO 09 DEC 2004

ELECTRICAL TREATMENT FOR OIL BASED DRILLING OR COMPLETIONFLUIDSField of the Invention

5 The present invention relates to an electrical treatment for oil based drilling or completion fluids.

Background

10 In the process of rotary drilling a well, a drilling fluid or mud is circulated down the rotating drill pipe, through the bit, and up the annular space between the pipe and the formation or steel casing, to the surface. The drilling fluid performs different functions such as removal of cuttings from the bottom of the hole to the surface, to suspend cuttings and weighting material when the circulation is interrupted, control subsurface pressure, isolate the
15 fluids from the formation by providing sufficient hydrostatic pressure to prevent the ingress of formation fluids into the wellbore, cool and lubricate the drill string and bit, maximise penetration rate etc.

20 The required functions can be achieved by a wide range of fluids composed of various combinations of solids, liquids and gases and classified according to the constitution of the continuous phase mainly in two groupings: aqueous drilling fluids, and oil based drilling fluids.

25 Aqueous fluids are the most commonly used drilling fluid type. The aqueous phase is made up of fresh water or, more often, of a brine. As discontinuous phase, they may contain gases, water-immiscible fluids such as diesel oil which form an oil-in-water emulsion, and solids including clays and weighting material such as barite. The properties are
30 typically controlled by the addition of clay minerals, polymers and surfactants.

In drilling water-sensitive zones such as reactive shales, production formations, or where bottom hole temperature conditions are severe or where corrosion is a major problem, oil based drilling fluids are preferred. The continuous phase is typically a mineral or synthetic oil which may be alkenic, olefenic, esteric etc. Such fluids also commonly contain water or brine as discontinuous phase to form a water-in-oil or invert emulsion. Generally they furthermore contain a solid phase, which is essentially similar to that of aqueous fluids, and additives for the control of density, rheology and fluid loss. The invert emulsion is formed and stabilised with the aid of one or more specially selected emulsifiers.

Oil based drilling fluids also typically contain oil-soluble surfactants that facilitate the incorporation of water-wet clay or non-clay formation minerals, and hence enable such minerals to be transported to surface equipment for removal from circulation before the fluid returns to the drillpipe and the drillbit. The largest formation particles are rock cuttings, of size typically larger than 0.1 - 0.2 mm, removed by shale-shaker screens at the surface. Smaller particles, typically larger than about 5 μm , will pass through the screens, but can be removed by centrifuge.

Oil based drilling fluids have been used for many years, and their application is expected to increase, partly owing to their several advantages over water based drilling fluids, but also owing to their ability to be re-used and re-cycled, so minimizing their loss and their environmental impact.

As mentioned above, during drilling, formation particles become incorporated into the drilling fluid. Unless these are removed, they eventually move the fluid's properties, particularly the rheological parameters, out of the acceptable range. However, formation particles that are

colloidal in size (less than about 5 μm) are more difficult to remove than the larger particles. A longer centrifuge run-time would be sufficient to remove the colloidal particles if the fluid were merely viscous, but the quiescent drilling fluid is usually required to behave as a gel to support cuttings in periods without circulation. Such a fluid will have a gel strength, and will behave as a non-Newtonian, shear-thinning fluid in which the viscosity at low shear rates is very large compared with the viscosity at the circulation rate.

Gel strengths typical of oil based fluids (1 -10 Pa) can be shown to support particles of less than a few microns in size indefinitely against the centrifugal force typical of oilfield centrifuges, which then have no effect regardless of the time they run. Further, owing to their large specific surface area, colloidal-sized particles have a disproportionate effect on the rheology of a fluid. Moreover, as more colloidal particles become part of the fluid, the gel strength will generally increase. Thus as more colloidal particles are incorporated in the drilling fluid, the upper particle size that can be supported by the gel, and hence unremoved by the centrifuge, also increases. Increasing quantities of colloidal particles are detrimental to other aspects of a fluid's performance, particularly those engineering parameters important for efficient drilling.

Thus, in practice, the process of increasing colloidal concentration and decreasing treatment efficiency tends to continue until engineering parameters depart from their acceptable ranges. In particular, both the engineering rheology parameters PV and YP (API 1988) must be kept within bounds for efficient drilling. As drilling proceeds, and possibly also as the fluid is moved from one job to another, the driller can eventually find that PV and YP increase

beyond their upper limits until the fluid becomes unusable for drilling and untreatable by centrifuge.

Typically PV should be in the range 20 to 100, and YP should lie between 15 to 55. Strictly, the PV and YP of drilling fluids are defined by the API-defined rheometer used to measure them, but they can be related to more generally used parameters by the Bingham Plastic rheology model in which the shear stress SS (in Pa) and shear rate SR (in reciprocal seconds or 1/s) are related by:

$$SS = BYS + BPV \times SR$$

where BYS is the Bingham yield stress in Pa and BPV is the Bingham plastic viscosity in Pa s. The oilfield unit YP as measured by the API method is given by $YP = 1.96 \times BYS(\text{Pa})$. Likewise, the oilfield unit PV = $1000 \times BPV(\text{Pa s})$.

Similar considerations apply to oil based completion fluids.

Summary of the Invention

In general terms, the present invention relates to an electrical treatment for oil based drilling or completion fluids whereby the particulate structure of the fluid and/or a filter cake or sedimentary bed formed from the fluid may be altered to give advantageous fluid, cake or bed properties. The drilling or completion fluids of the present invention generally have densities of at least 1100 kg/m^3 , and more preferably 1500 kg/m^3 or 2000 kg/m^3 .

One effect of applying a spatially uniform field, of e.g. 100 V mm^{-1} , to an oil based fluid, is to cause charged colloidal particles to migrate to an electrode at which they concentrate and collect as a removable deposit. This phenomenon is well-known as electrophoresis (Delgado 2002), particularly in aqueous or highly-conductive fluids. US

Patent No. 4,323,445 proposes an apparatus for electrokinetically separating water based drilling mud into liquid and solid phases. However, as far as we are aware, electrophoresis has not been exploited for the removal of colloidal or fine particles from oil based drilling or completion fluids, or any other similar non-aqueous application.

US 5,308,586 describes an electrostatic separator for removing very dilute fine particles from oils. However, in that application (i) the oil feed was relatively clean and free from the high concentrations of the weighting agents and emulsified brine typically found in drilling fluids, and (ii) the field was applied to the feed oil amongst a bed of glass beads.

Also it is known in the petroleum industry to apply very high electric fields for coalescing dispersed water droplets dispersed in oil (Thornton 1992, Eow et al. 2001). However, in general, the field strengths we propose are less than those at which emulsion droplets in an oil based drilling or completion fluid would coalesce to form continuous and electrically-conductive chains. Such fields, giving dielectric breakdown, are routinely measured in the API Electrical Stability Test (API 1988) for oil based drilling or completion fluids as a measure of emulsion stability and sufficiency of emulsifier.

Thus a first aspect of the present invention provides a method of removing particulate solids from an oil based drilling or completion fluid, comprising:

exposing the fluid to an electric field to electrically migrate particulate solids suspended therein, and collecting the migrated particulate solids to remove them from the fluid.

Typically, but not exclusively, the drilling or completion fluid comprises a water-in-oil emulsion. For such a fluid, the amount of water (in terms of the water to oil volume ratio) may be at least 5:95, and more preferably at least 30:70 or 50:50. The strength of the electric field is preferably lower than that required to coalesce the water droplets of the emulsion. The water generally contains a dissolved salt, i.e. the water is a brine.

Preferably, the strength of the electric field is less than 100,000 V/m, more preferably it is less than 10,000 V/m.

Preferably, the strength of the electric field is greater than 10 V/m, more preferably it is greater than 100 V/m.

In certain embodiments, the electric field is substantially uniform. However, in other embodiments the electric field is spatially non-uniform. One effect of non-uniform fields is well-known as dielectrophoresis (Pohl 1978) whereby the field induces an electric dipole moment in an uncharged particle of different electrical permittivity from the surrounding liquid. The particle is then caused by the field gradient to migrate towards the high-field region where it can be collected. An advantage of the use of a non-uniform field is, therefore, that the migrating particles are not required to possess an electrical charge.

The PV and/or YP of the drilling or completion fluid is typically reduced as a result of the collection of the particulate solids.

Generally, the fluid contains clay particles and/or weighting agent (e.g. barite) particles.

The particulate solids in the fluid may occupy at least 5 vol. % and preferably at least 15 vol. % of the total fluid.

The drilling or completion fluid may be a shear-thinning fluid which forms a gel when quiescent. Thus the method allows colloidal particles to be removed from such a fluid.

5 In preferred embodiment electrodes used to generate the electrical field are combined with a deposit removal system that either collects deposits from a location in the vicinity of the electrode or actively removes deposits from the surface of the electrode. The removal system may be operating continuously or as a batch process. In the latter case, it is
10 preferred to operate the removal system during periods in which the electric field is switched off.

The method is further preferably applied such that voltage applied and current are proportional, hence that the fluid behaves as a conventional resistor following Ohm's law.

15 The method may further comprise heating the fluid to enhance the collection of particulate solids. Preferably the fluid is heated to a temperature of at least 25°C, more preferably at least 50°C, and even more preferably at least 75°C.

A further aspect of the invention provides a method of
20 recycling an oil based drilling or completion fluid by performing the method of the first aspect.

The method of recycling may include the step of using a centrifuge or hydrocyclone to remove other particulate solids from the fluid. This step may be performed before or after
25 the electrical treatment.

Brief Description of the Drawings

The invention will now be described in more detail, with reference to the drawings in which:

Figure 1 shows schematically a simple electrophoretic
30 separating assembly;

Figure 2 shows schematically an apparatus used for quantitative electrophoretic separating tests;

Figure 3 is a graph of mass of deposit against voltage;

Figure 4 shows a further graph of mass of deposit against
5 voltage;

Figure 5 shows a graph of current against voltage;

Figure 6 shows a graph of deposit weight against rotor speed;

Figure 7 shows a graph of deposit weight against test temperature;

10 Figure 8 shows schematically a longitudinal section through a device for recycling oil based mud; and

Figures 9a and b respectively show longitudinal and transverse sections of an alternative device for recycling oil based mud.

15 Detailed Description

Tests have been performed on oil based drilling fluids in which a steady electrical field was applied to a sample of oil based mud to remove solid particles by depositing them on one electrode, leaving the drilling fluid depleted of such
20 particles. In most cases the deposit was formed on the negative electrode, which suggests that the particles were positively-charged, but the process is equally applicable to the treatment of fluids containing negatively-charged particles.

25 *Drilling fluids*

Initial tests were conducted with field samples in which the base oil was mineral oil. The field samples were a conventional invert emulsion based on a Versaclean™ oil

based mud (OBM) formulation. These are tightly emulsified, temperature-stable, invert-emulsion, oil based drilling fluids. The following components are found in such formulations: primary and secondary emulsifiers, blends of liquid emulsifiers, wetting agents, gellants, fluid stabilizing agents, organophilic clay (amine treated bentonite), CaCl_2 brine, filtration control additives and barite as a weighting agent. The field sample drilling fluids were aged by circulation at geothermal temperatures, and contained some fine particles, typically clay, resulting from the drilling process.

Further tests were also conducted on field samples of a VersaportTM OBM system. The Versaport systems have elevated low shear rate viscosities. Versaport is either a conventional or relaxed filtrate system, the relaxed filtrate system comprising: primary emulsifier, surfactant, oil-wetting agents, lime, viscosifiers and gelling agents, organophilic clay, CaCl_2 brine and barite.

Apparatus and tests on Versaclean

Qualitative tests were made on the field-fluid Versaclean OBM samples, using a simple electrophoretic separating assembly shown schematically in Figure 1. The assembly had a container 21 for two parallel stainless steel plates 22 and the sample 23 to be tested. The plates were connected to a constant DC voltage supply of about 200 V, so that one electrode was negative and the other positive, and a field strength of about 1000 V/cm was generated. After a few minutes oil appeared close to the electrodes, and after about 20 min the assembly was dismantled. The negative electrode was coated with about 0.5 mm of deposit 24, the other remaining deposit-free but coated thinly with drilling fluid. With this arrangement of plates, the field was kept spatially-uniform by means of a guard electrode (not shown).

Thus the presence of a uniformly-thick deposit over the negative electrode was evidence that deposition resulted from electrophoresis of positive particles, rather than dielectrophoresis which requires a field gradient.

5 An apparatus used for quantitative tests is shown schematically in Figure 2. The apparatus consisted of a cylindrical epoxy conductivity cell 25 of internal diameter about 20 mm, having three axially spaced annular carbon electrodes 26. The electrodes were connected to a constant
10 voltage supply so that the centre electrode was negatively charged and the other two were positively charged. Versaclean was poured into this cell and a constant voltage applied. A layer of oil 27 was observed to form at the surface of the mud 28 and an electro-deposit 29 collected on
15 the negative electrode. A barite layer 30 settled at the bottom of the cell. The oil is believed to rise to the surface owing to a weakening of the gel as fine particles migrated from the centre of the cell to form the deposit. The cell was weighed empty, and then after the treated
20 drilling fluid (effluante) was poured out. The increment of weight comprised the weight of the deposit and the residual fluid unremoved by gravity that adhered to the inside of the cell. The API rheological parameters PV and YP, and the API 100 PSI fluid loss, were measured for the effluante poured
25 from the cell.

The effect of voltage and time on the mass of the deposit is shown in Figure 3. Closed circles show the electrodeposit mass after 25 min. Open circles show the mass deposited after 40 minutes corrected to 25 min assuming the
30 electrodeposit was directly proportional to the time of voltage application. The collected data show that the mass deposited was proportional to voltage and time.

A variety of different oil based drilling fluids were then investigated with the epoxy cell method, in which a voltage of 200 V was applied for a duration of 25 minutes. These fluids were two different field samples of Versaclean (Versaclean 1 and Versaclean 2), and a further sample of Versaclean 2 which has been centrifuged at 3000 rpm for 20 min to remove barite. Measurements of the electrical stability and density of the untreated muds and of PV and YP before and after treatment are shown in Table 1.

Table 1: Properties of field and laboratory OBMs

	API Electrical Stability (untreated) (V)	Density (untreated) (g/ml)	PV (untreated)	PV (treated)	YP (untreated)	YP (treated)
Versaclean 1	517	1.45	78	69	37	32
Versaclean 2	435	1.455	58	52	30	25
Versaclean 2 Barite-free	449	1.025	39	32.5	28	27.5

Thus the PV and YP of all the Versaclean OBMs were reduced by the treatment.

Figure 4 shows a graph of the mass of the electrodeposit against voltage for each of the OBMs, including the Versaport OBM. This shows that the electrodeposit mass depends on the density of the mud, suggesting that the fine particles attracted to the negative electrode tend to trap the barite. The graph also shows that high voltages do not necessarily provide a greater electrodeposit. For all the field muds the electrodeposit mass reached a maximum between 450 to 500 V. The collection process becomes less efficient as the applied voltage approached the breakdown voltage of the API Electrical Stability test (API 1988), possibly owing to a drop in the electric field experienced by the oil phase as chains of emulsion droplets begin to form prior to dielectric breakdown (Growcock et al. 1994).

Non-ohmicity and time-dependence

Using the apparatus of Figure 2 electrophoretic separation was performed on Versaclean OBM for various times and voltages and the current measured. Figure 5 shows a graph of current against voltage. The current was observed to increase with voltage in typical ohmic behaviour up to 200 V but at higher voltages there was a clear non-ohmic and time-dependent behaviour. This suggests a complex conduction mechanism which corresponds with the observation that as the applied voltage approaches the breakdown voltage progressively less deposit is collected on the negative electrode. These results again suggest that the electrodeposition process is more effective at voltages less than the breakdown voltage of the API Electrical Stability test (API 1988).

In tests on Versaclean, the total solids content by weight in the deposit was found to be about 64%wt while that of the mud was 57%wt, showing that the deposit solids were more concentrated than in the drilling fluid. Similarly, the electrodeposit yield stress was about five times that of the untreated mud, suggesting that the deposit had more fine clay particles than the mud.

Measurements of the concentration by weight of metal species in the deposit and mud were made using inductively-coupled plasma metal analysis, and the results are shown in Table 2.

Table 2: Elemental analysis of deposit and mud

	Al/Ba	Al/Cl	Al/C	Al/Ca	Ba/C
Mud	0.185	0.356	0.025	0.207	0.136
Deposit	0.21	0.487	0.034	0.208	0.16
Deposit/mud % increase	15%	37%	36%	0%	18%

Assuming the clay to be the only source of Al, the ratios of Al to Ba, Cl and C suggest that the deposit has gained

significantly in clay. The null change in Al/Ca suggests that some Ca may be bonded to the clay, and the 18% increase in the Ba/C ratio shows that there was less oil in the deposit.

5 *Effect of shear on field mud (Versaclean)*

The effect of shear on the electrodeposition process was investigated using a modified Chan 35TM oilfield rheometer in which the outside of the rotor was electrically-isolated from the rheometer body and acted as one electrode, while a brass
10 cup of inner diameter 57 mm was inserted into a heat cup to act as the rheometer stator and also the other (earthed/grounded) electrode. In this configuration the drilling fluid could be sheared in the gap between the rotor and stator and the deposit could be collected on the outside
15 of the rotor. The rotor gave a larger collection surface area than the annular electrode of the epoxy cell of Fig. 2, while allowing the mud to be sheared and/or heated simultaneously with the electric field applied.

Using the Chan rotor R1 outer diameter of 40.65 mm and a
20 brass cup inner diameter of 57.00 mm gave a laminar shear rate per unit RPM at the surface of the rotor of 0.43 s⁻¹/RPM. The results are shown in Table 3. Some results are also plotted on Figure 6, which is a graph of deposit weight against rotor speed. Figure 6 demonstrates that the effect
25 of shear was to reduce the amount of deposit.

Table 3: Effect of shear, voltage, and time on electrodeposit mass for field Versaclean OBM

Rotor speed (RPM)	Applied voltage (V)	Treatment time (min)	Deposit weight (g)	PV post-treatment	YP post-treatment
0	0	0	-	58	30
200	0	25	-	52	27
200	0	100	-	45.5	30
0	40	250	32.7	43	23
0	400	40	41.60	30	11
0	400	25	35.72	37	16
20	400	25	27.8	36	26
100	400	25	22.29	45	15
200	400	25	16.72	48	18
200	400	40	19.59	40	18
200	400	60	23.29	41	7

These results, together with a range of tests on samples of used field Versaclean OBM and lab Versaport OBM may be summarized as follows:

- With no shear, the longer the exposure to the electrical field, the greater the amount of deposit and the lower PV and YP.
- The deposit weight increases with both time and voltage in both static and sheared tests. The very low voltage test over a long time (40V at 250 min) produced a similar deposit to 400 V at 25 min.
- PV and YP were reduced as the deposit increased.
- Elemental analysis after treatment of the Versaport mud indicated that the electro-deposit was enriched in Ba, Ca, Al, Na, Cl and depleted in organics (C, H, N) compared to the original mud. The reverse was found in the treated mud, confirming solids-removal from the fluid.
- Shear reduced the mass of electro-deposit (see Figure 6) and the effect of electro-treatment on the rheology. Sheared electro-deposits were also more fluid than static electro-deposits.

- Combinations of static and sheared periods of electro-treatment generally increased the electro-deposit. The order of imposition of electric field and shear appears to have an effect on rheology.
- 5 • Reversal of the field polarity causes the deposit to detach from the electrode and slump to the bottom.

Other variations altering the sequence of electrical treatment and shear in two stages were attempted and the results are shown in Table 4. The mud was treated first for 10 25 min with an applied voltage of 400 V with no shear. Then the treated system was placed under a shear of 200 rpm for 25 min. The amount of deposit formed was higher and PV and YP was generally lower than that when the mud was subjected to a simultaneous electric field and shear. Reversing the order 15 of this process resulted in a higher amount of material being deposited but also a higher PV and YP.

Table 4: Two phase test conditions and results of experiments investigating effect of a treatment combining shear and voltage on weight of deposit, PV and YP (Versaclean field- 20 OBM)

Rotor speed (RPM)		Applied voltage (V)		Time (mn)		Deposit weight (g)	PV (treated)	YP (treated)
Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2			
0	200	400	0	25	25	27.27	22	20
200	0	0	400	25	25	31.58	44	21
200	200	0	400	25	25	17.49	43	20

Effect of temperature on field mud (Versaclean)

Figure 7 is a graph of deposit weight against test temperature obtained by testing the Versaclean OBM in the modified Chan rheometer. The effect of increasing the 25 temperature, at a fixed voltage, was to usefully increase the weight of the deposit. Decreases in PV and YP, measured at

laboratory temperature after treatment, are also shown in the graph.

Continuous-flow and batch embodiments

The experiments described above show the utility of treating
 5 oil based drilling or completion fluids with an electric
 field. We now propose continuous-flow and batch embodiments
 that may be useful in full-scale or engineering applications.
 These serve to demonstrate the application of the invention
 but other examples are possible.

10 Figure 8 shows schematically a longitudinal section through a
 continuous-flow device for recycling used OBM. The drilling
 or completion fluid 1 enters an electrically-conductive and
 horizontal pipe 2, which bifurcates into pipe 3 and 4, each
 branch containing a valve 5 and 6. A series of annular
 15 electrodes 7 are held in pipe 2 and insulated from it by
 means of insulators 8. Electrical contact to each annular
 electrode is made via leads 9 and insulating bushes 10.
 Leads 11 and 12 respectively connect the electrodes and the
 pipe 2 to an electrical supply. In operation electrodeposit
 20 13 forms on each of electrodes 7.

We have found (see above) that shear tends to reduce the
 efficiency of the deposition process. However, Figure 6
 shows that at sufficiently low shear rates, the efficiency is
 largely undiminished. For example, Figure 6 shows that 10
 25 RPM had little effect on the deposition rate. In our
 modified Chan 35 oilfield rheometer, 10 RPM corresponds to
 about 4.3 s^{-1} . For a pipe of diameter D , the relation
 between wall shear rate (WSR), volumetric flow rate (Q) and
 mean axial velocity (V) is $\text{WSR} = 16V/(3D) = 64Q/(3\pi D^3)$. This
 30 sets an upper limit on V and Q , in order that the deposition
 process is not unduly lessened. For example, for $D = 0.1 \text{ m}$

and $WSR = 4.3 \text{ s}^{-1}$, $V = 0.22 \text{ m s}^{-1}$, approximately, which corresponds to about 100 l min^{-1} .

The device operates as follows. Deposit is collected on electrodes 7 with valve 5 open and valve 6 closed. Pipe 3 then exudes a drilling fluid with less fine particles than entered via pipe 2. After sufficient time (to be found by experiment and corresponding to a lessening deposition rate as the deposit intrudes into the body of pipe 2) valve 5 is closed, valve 6 is simultaneously opened, and the voltage applied to form the deposit is reversed. This pushes deposit into the body of pipe 2, where its greater density than the surrounding fluid causes it to be preferentially collected by pipe 4 and led into a suitable collection vessel.

An alternative continuous-flow embodiment for such a device is shown in longitudinal section in Figure 9a and in transverse section in Figure 9b. In this case the drilling or completion fluid 1' enters a horizontal pipe 2' which is an electrical insulator. Pipes 3' and 4', with valves 5' and 6', resemble the bifurcation and valves of the device shown in Figure 8. Electrodes 7' and 7'' now run axially along pipe 2', and are connected to a voltage source via leads 11' and 12', such that the electro-deposit 13' collects along the lower electrode 7'' over a suitable time period and voltage, both to be determined by experiment. Pipe 3' then exudes a fluid with less fine particles than entered via pipe 2'. After sufficient deposit is collected, the flow is stopped; valves 5' and 6' are closed and opened, respectively, the voltage is reversed, and the flow re-started. The re-start flow rate should be large enough to quickly remove the deposit, but not so large as to remix it with the incoming fluid. The deposit then exudes via pipe 4' and led to a suitable collection vessel.

The above two examples are illustrative of a variety of possible deposit removal systems, which may also include scraper-type devices or similar apparatus.

While the invention has been described in conjunction with
5 the exemplary embodiments described above, many equivalent
modifications and variations will be apparent to those
skilled in the art when given this disclosure. For example,
in batch embodiments the electrodes may be set into a stirred
or a static tank. Accordingly, the exemplary embodiments of
10 the invention set forth above are considered to be
illustrative and not limiting. Various changes to the
described embodiments may be made without departing from the
spirit and scope of the invention.

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Claims

1. A method of removing particulate solids from an oil based drilling or completion fluid, comprising:
 exposing the fluid to an electric field to electrically
5 migrate particulate solids suspended therein, and
 collecting the migrated particulate solids to remove them from the fluid.
2. A method according to claim 1, wherein the fluid comprises a water-in-oil emulsion, and the strength of the
10 electric field is lower than that required to coalesce the water droplets of the emulsion.
3. A method according to claim 1 or 2, wherein the strength of the electric field is less than 100,000 V/m.
4. A method according to any one of the previous claims,
15 wherein the strength of the electric field is controlled such that current and voltage remain proportional to each other.
5. A method according to any one of the previous claims, wherein the PV and/or YP of the fluid are reduced as a result of the collection of the particulate solids.
- 20 6. A method according to any one of the previous claims, wherein the fluid contains clay particles.
7. A method according to any one of the previous claims, wherein the fluid contains weighting agent particles.
8. A method according to any one of the previous claims,
25 wherein the particulate solids in the fluid occupy at least 5 vol. % of the total fluid.
9. A method according to any one of the previous claims, wherein the fluid is a shear-thinning fluid which forms a gel when quiescent.

10. A method according to any one of the previous claims, further comprising heating the fluid to enhance the collection of particulate solids.
11. A method of recycling an oil based drilling or completion fluid by performing the method of any one of the previous claims.
12. A method according to claim 11, including the step of using a centrifuge or hydrocyclone to remove other particulate solids from the fluid.
13. A method according to claim 1, including the step of using at least two electrodes to generate the electric field.
14. A method according to claim 1, including the step of using at least two electrodes to generate the electric field and a deposit removal system co-located with the electrodes.
15. A method according to claim 14, wherein deposit removal system is operated continuously or as a batch process.
16. An apparatus for removing particulate solids from an oil based drilling or completion fluid, comprising:
electrodes adapted to expose the fluid to an electric field to electrically migrate particulate solids suspended therein, and
a deposit removal system for collecting the migrated particulate solids to remove them from the fluid.

ABSTRACT

A method of removing particulate solids from an oil based drilling or completion fluid is disclosed. The method involves exposing the fluid to an electric field to
5 electrically migrate particulate solids suspended therein, and collecting the migrated particulate solids to remove them from the fluid.



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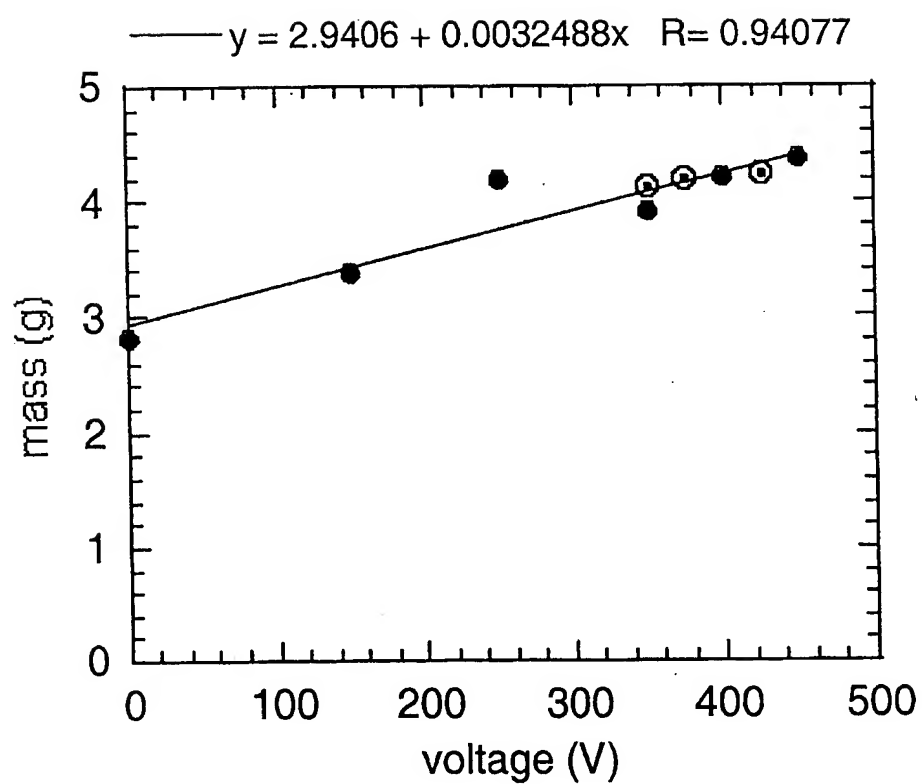


Figure 3

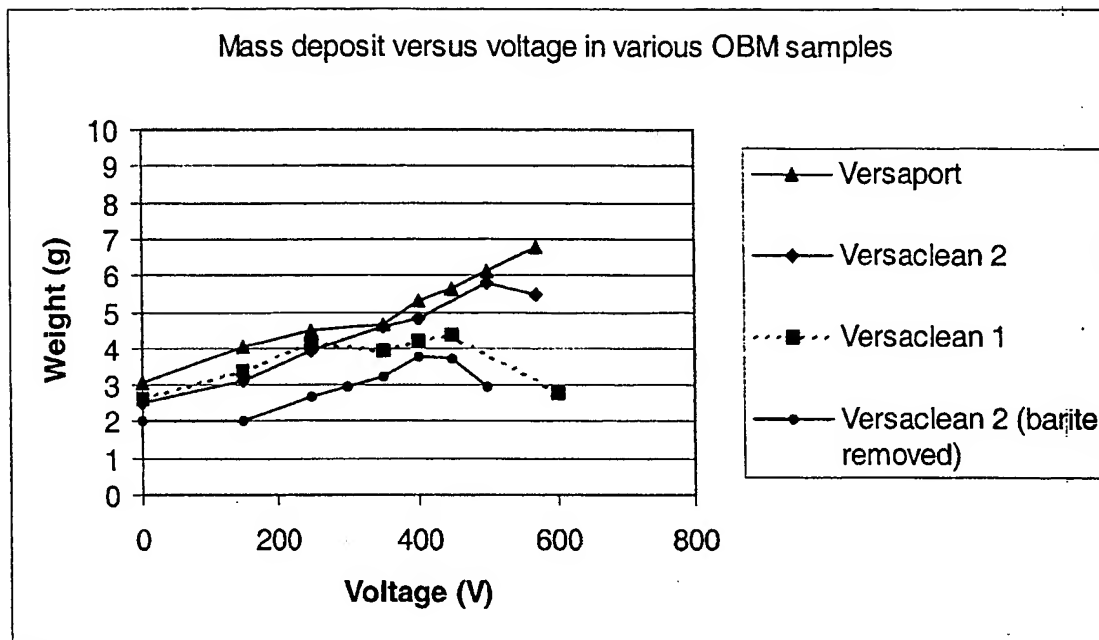


Figure 4

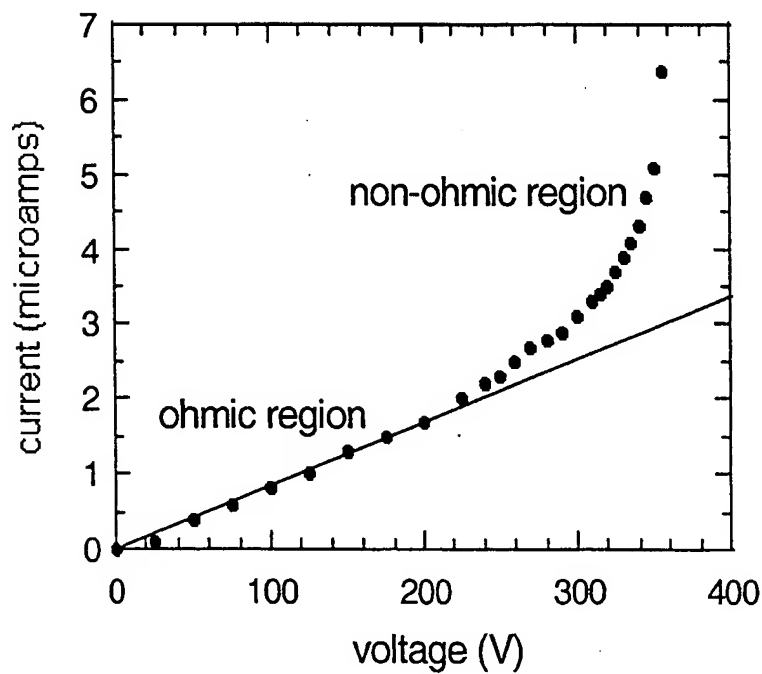


Figure 5

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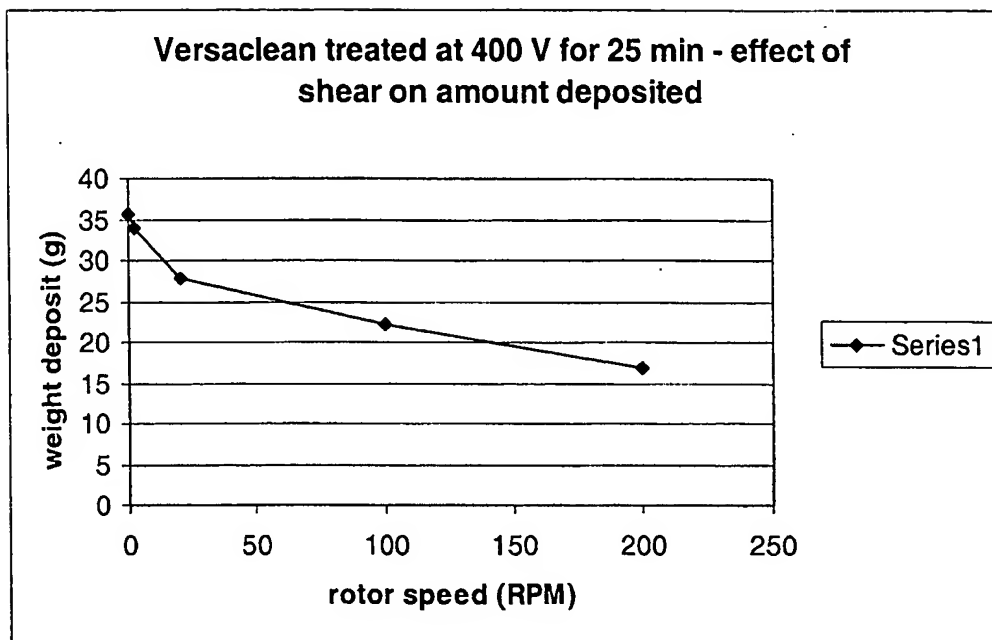


Figure 6

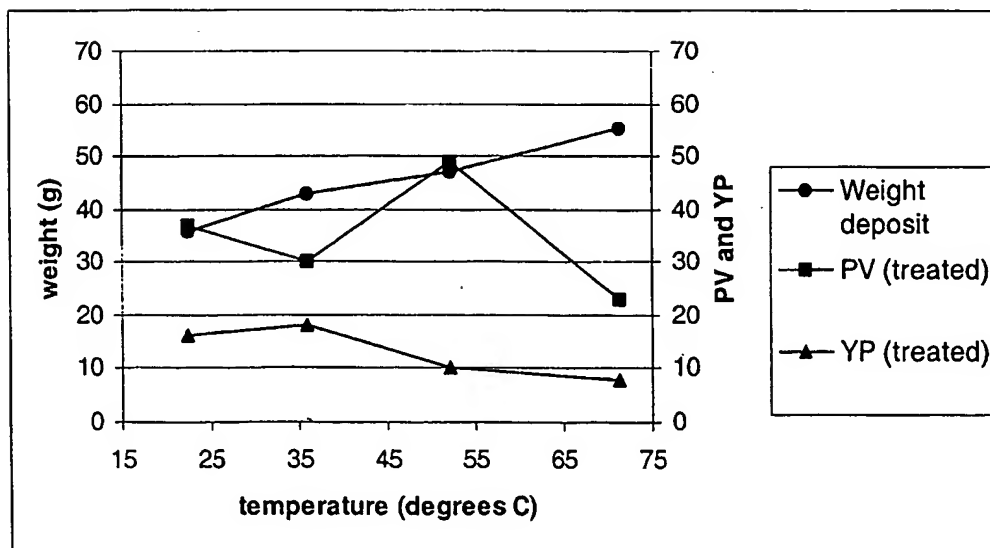


Figure 7

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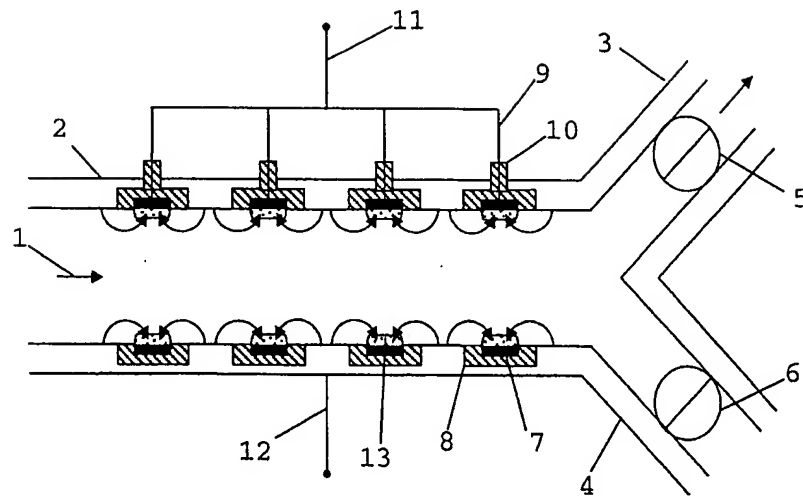


Figure 8

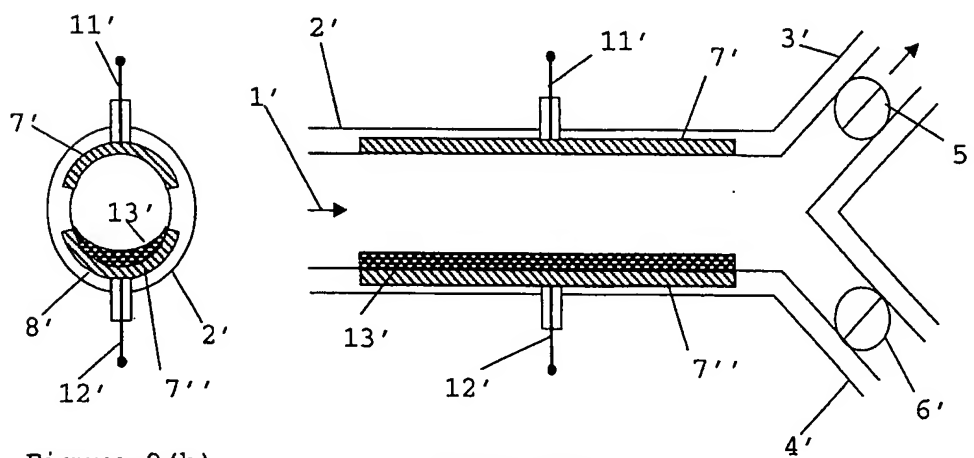


Figure 9(b)

Figure 9(a)

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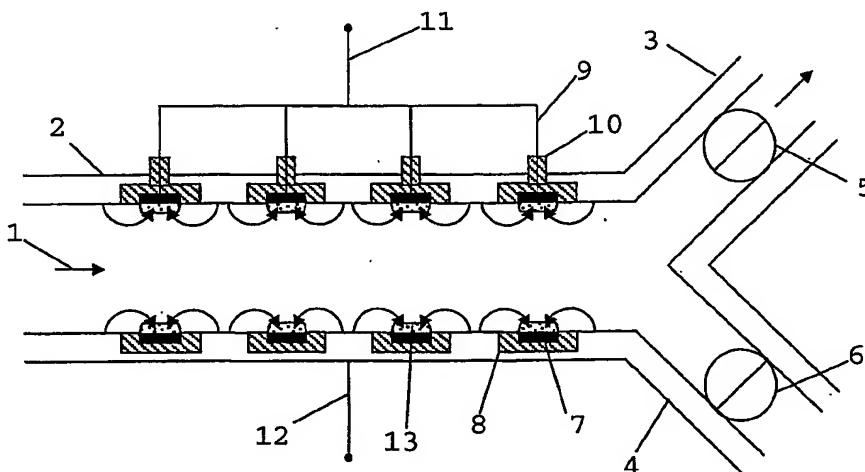
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(54) Title: ELECTRICAL TREATMENT FOR OIL BASED DRILLING OR COMPLETION FLUIDS



(57) Abstract: A method of removing particulate solids from an oil based drilling or completion fluid (1) is disclosed. The method involves exposing the fluid to an electric field to electrically migrate particulate solids suspended therein, and collecting the migrated particulate solids to remove them from the fluid.

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

ELECTRICAL TREATMENT FOR OIL BASED DRILLING OR COMPLETION
FLUIDS

Field of the Invention

The present invention relates to an electrical treatment for
5 oil based drilling or completion fluids.

Background

In the process of rotary drilling a well, a drilling fluid or
mud is circulated down the rotating drill pipe, through the
bit, and up the annular space between the pipe and the
10 formation or steel casing, to the surface. The drilling
fluid performs different functions such as removal of
cuttings from the bottom of the hole to the surface, to
suspend cuttings and weighting material when the circulation
is interrupted, control subsurface pressure, isolate the
15 fluids from the formation by providing sufficient hydrostatic
pressure to prevent the ingress of formation fluids into the
wellbore, cool and lubricate the drill string and bit,
maximise penetration rate etc.

The required functions can be achieved by a wide range of
20 fluids composed of various combinations of solids, liquids
and gases and classified according to the constitution of the
continuous phase mainly in two groupings: aqueous drilling
fluids, and oil based drilling fluids.

Aqueous fluids are the most commonly used drilling fluid
25 type. The aqueous phase is made up of fresh water or, more
often, of a brine. As discontinuous phase, they may contain
gases, water-immiscible fluids such as diesel oil which form
an oil-in-water emulsion, and solids including clays and
weighting material such as barite. The properties are
30 typically controlled by the addition of clay minerals,
polymers and surfactants.

In drilling water-sensitive zones such as reactive shales, production formations, or where bottom hole temperature conditions are severe or where corrosion is a major problem, oil based drilling fluids are preferred. The continuous phase is typically a mineral or synthetic oil which may be alkenic, olefenic, esteric etc. Such fluids also commonly contain water or brine as discontinuous phase to form a water-in-oil or invert emulsion. Generally they furthermore contain a solid phase, which is essentially similar to that of aqueous fluids, and additives for the control of density, rheology and fluid loss. The invert emulsion is formed and stabilised with the aid of one or more specially selected emulsifiers.

Oil based drilling fluids also typically contain oil-soluble surfactants that facilitate the incorporation of water-wet clay or non-clay formation minerals, and hence enable such minerals to be transported to surface equipment for removal from circulation before the fluid returns to the drillpipe and the drillbit. The largest formation particles are rock cuttings, of size typically larger than 0.1 - 0.2 mm, removed by shale-shaker screens at the surface. Smaller particles, typically larger than about 5 μm , will pass through the screens, but can be removed by centrifuge.

Oil based drilling fluids have been used for many years, and their application is expected to increase, partly owing to their several advantages over water based drilling fluids, but also owing to their ability to be re-used and re-cycled, so minimizing their loss and their environmental impact.

As mentioned above, during drilling, formation particles become incorporated into the drilling fluid. Unless these are removed, they eventually move the fluid's properties, particularly the rheological parameters, out of the acceptable range. However, formation particles that are

colloidal in size (less than about 5 μm) are more difficult to remove than the larger particles. A longer centrifuge run-time would be sufficient to remove the colloidal particles if the fluid were merely viscous, but the quiescent drilling fluid is usually required to behave as a gel to support cuttings in periods without circulation. Such a fluid will have a gel strength, and will behave as a non-Newtonian, shear-thinning fluid in which the viscosity at low shear rates is very large compared with the viscosity at the circulation rate.

Gel strengths typical of oil based fluids (1 -10 Pa) can be shown to support particles of less than a few microns in size indefinitely against the centrifugal force typical of oilfield centrifuges, which then have no effect regardless of the time they run. Further, owing to their large specific surface area, colloidal-sized particles have a disproportionate effect on the rheology of a fluid. Moreover, as more colloidal particles become part of the fluid, the gel strength will generally increase. Thus as more colloidal particles are incorporated in the drilling fluid, the upper particle size that can be supported by the gel, and hence unremoved by the centrifuge, also increases. Increasing quantities of colloidal particles are detrimental to other aspects of a fluid's performance, particularly those engineering parameters important for efficient drilling.

Thus, in practice, the process of increasing colloidal concentration and decreasing treatment efficiency tends to continue until engineering parameters depart from their acceptable ranges. In particular, both the engineering rheology parameters PV and YP (API 1988) must be kept within bounds for efficient drilling. As drilling proceeds, and possibly also as the fluid is moved from one job to another, the driller can eventually find that PV and YP increase

beyond their upper limits until the fluid becomes unusable for drilling and untreatable by centrifuge.

Typically PV should be in the range 20 to 100, and YP should lie between 15 to 55. Strictly, the PV and YP of drilling fluids are defined by the API-defined rheometer used to measure them, but they can be related to more generally used parameters by the Bingham Plastic rheology model in which the shear stress SS (in Pa) and shear rate SR (in reciprocal seconds or 1/s) are related by:

$$SS = BYS + BPV \times SR$$

where BYS is the Bingham yield stress in Pa and BPV is the Bingham plastic viscosity in Pa s. The oilfield unit YP as measured by the API method is given by $YP = 1.96 \times BYS(\text{Pa})$. Likewise, the oilfield unit PV = $1000 \times BPV(\text{Pa s})$.

Similar considerations apply to oil based completion fluids.

Summary of the Invention

In general terms, the present invention relates to an electrical treatment for oil based drilling or completion fluids whereby the particulate structure of the fluid and/or a filter cake or sedimentary bed formed from the fluid may be altered to give advantageous fluid, cake or bed properties. The drilling or completion fluids of the present invention generally have densities of at least 1100 kg/m³, and more preferably 1500 kg/m or 2000 kg/m.

One effect of applying a spatially uniform field, of e.g. 100 V mm⁻¹, to an oil based fluid, is to cause charged colloidal particles to migrate to an electrode at which they concentrate and collect as a removable deposit. This phenomenon is well-known as electrophoresis (Delgado 2002), particularly in aqueous or highly-conductive fluids. US

Patent No. 4,323,445 proposes an apparatus for electrokinetically separating water based drilling mud into liquid and solid phases. However, as far as we are aware, electrophoresis has not been exploited for the removal of colloidal or fine particles from oil based drilling or completion fluids, or any other similar non-aqueous application.

US 5,308,586 describes an electrostatic separator for removing very dilute fine particles from oils. However, in that application (i) the oil feed was relatively clean and free from the high concentrations of the weighting agents and emulsified brine typically found in drilling fluids, and (ii) the field was applied to the feed oil amongst a bed of glass beads.

Also it is known in the petroleum industry to apply very high electric fields for coalescing dispersed water droplets dispersed in oil (Thornton 1992, Eow et al. 2001). However, in general, the field strengths we propose are less than those at which emulsion droplets in an oil based drilling or completion fluid would coalesce to form continuous and electrically-conductive chains. Such fields, giving dielectric breakdown, are routinely measured in the API Electrical Stability Test (API 1988) for oil based drilling or completion fluids as a measure of emulsion stability and sufficiency of emulsifier.

Thus a first aspect of the present invention provides a method of removing particulate solids from an oil based drilling or completion fluid, comprising:

exposing the fluid to an electric field to electrically migrate particulate solids suspended therein, and collecting the migrated particulate solids to remove them from the fluid.

Typically, but not exclusively, the drilling or completion fluid comprises a water-in-oil emulsion. For such a fluid, the amount of water (in terms of the water to oil volume ratio) may be at least 5:95, and more preferably at least 30:70 or 50:50. The strength of the electric field is preferably lower than that required to coalesce the water droplets of the emulsion. The water generally contains a dissolved salt, i.e. the water is a brine.

Preferably, the strength of the electric field is less than 100,000 V/m, more preferably it is less than 10,000 V/m.

Preferably, the strength of the electric field is greater than 10 V/m, more preferably it is greater than 100 V/m.

In certain embodiments, the electric field is substantially uniform. However, in other embodiments the electric field is spatially non-uniform. One effect of non-uniform fields is well-known as dielectrophoresis (Pohl 1978) whereby the field induces an electric dipole moment in an uncharged particle of different electrical permittivity from the surrounding liquid. The particle is then caused by the field gradient to migrate towards the high-field region where it can be collected. An advantage of the use of a non-uniform field is, therefore, that the migrating particles are not required to possess an electrical charge.

The PV and/or YP of the drilling or completion fluid is typically reduced as a result of the collection of the particulate solids.

Generally, the fluid contains clay particles and/or weighting agent (e.g. barite) particles.

The particulate solids in the fluid may occupy at least 5 vol. % and preferably at least 15 vol. % of the total fluid.

The drilling or completion fluid may be a shear-thinning fluid which forms a gel when quiescent. Thus the method allows colloidal particles to be removed from such a fluid.

In preferred embodiment electrodes used to generate the electrical field are combined with a deposit removal system that either collects deposits from a location in the vicinity of the electrode or actively removes deposits from the surface of the electrode. The removal system may be operating continuously or as a batch process. In the latter case, it is preferred to operate the removal system during periods in which the electric field is switched off.

The method is further preferably applied such that voltage applied and current are proportional, hence that the fluid behaves as a conventional resistor following Ohm's law.

The method may further comprise heating the fluid to enhance the collection of particulate solids. Preferably the fluid is heated to a temperature of at least 25°C, more preferably at least 50°C, and even more preferably at least 75°C.

A further aspect of the invention provides a method of recycling an oil based drilling or completion fluid by performing the method of the first aspect.

The method of recycling may include the step of using a centrifuge or hydrocyclone to remove other particulate solids from the fluid. This step may be performed before or after the electrical treatment.

Brief Description of the Drawings

The invention will now be described in more detail, with reference to the drawings in which:

Figure 1 shows schematically a simple electrophoretic separating assembly;

Figure 2 shows schematically an apparatus used for quantitative electrophoretic separating tests;

Figure 3 is a graph of mass of deposit against voltage;

Figure 4 shows a further graph of mass of deposit against voltage;

Figure 5 shows a graph of current against voltage;

Figure 6 shows a graph of deposit weight against rotor speed;

Figure 7 shows a graph of deposit weight against test temperature;

Figure 8 shows schematically a longitudinal section through a device for recycling oil based mud; and

Figures 9a and b respectively show longitudinal and transverse sections of an alternative device for recycling oil based mud.

Detailed Description

Tests have been performed on oil based drilling fluids in which a steady electrical field was applied to a sample of oil based mud to remove solid particles by depositing them on one electrode, leaving the drilling fluid depleted of such particles. In most cases the deposit was formed on the negative electrode, which suggests that the particles were positively-charged, but the process is equally applicable to the treatment of fluids containing negatively-charged particles.

Drilling fluids

Initial tests were conducted with field samples in which the base oil was mineral oil. The field samples were a conventional invert emulsion based on a VersacleanTM oil

based mud (OBM) formulation. These are tightly emulsified, temperature-stable, invert-emulsion, oil based drilling fluids. The following components are found in such formulations: primary and secondary emulsifiers, blends of liquid emulsifiers, wetting agents, gellants, fluid stabilizing agents, organophilic clay (amine treated bentonite), CaCl_2 brine, filtration control additives and barite as a weighting agent. The field sample drilling fluids were aged by circulation at geothermal temperatures, and contained some fine particles, typically clay, resulting from the drilling process.

Further tests were also conducted on field samples of a VersaportTM OBM system. The Versaport systems have elevated low shear rate viscosities. Versaport is either a conventional or relaxed filtrate system, the relaxed filtrate system comprising: primary emulsifier, surfactant, oil-wetting agents, lime, viscosifiers and gelling agents, organophilic clay, CaCl_2 brine and barite.

Apparatus and tests on Versaclean

Qualitative tests were made on the field-fluid Versaclean OBM samples, using a simple electrophoretic separating assembly shown schematically in Figure 1. The assembly had a container 21 for two parallel stainless steel plates 22 and the sample 23 to be tested. The plates were connected to a constant DC voltage supply of about 200 V, so that one electrode was negative and the other positive, and a field strength of about 1000 V/cm was generated. After a few minutes oil appeared close to the electrodes, and after about 20 min the assembly was dismantled. The negative electrode was coated with about 0.5 mm of deposit 24, the other remaining deposit-free but coated thinly with drilling fluid. With this arrangement of plates, the field was kept spatially-uniform by means of a guard electrode (not shown).

Thus the presence of a uniformly-thick deposit over the negative electrode was evidence that deposition resulted from electrophoresis of positive particles, rather than dielectrophoresis which requires a field gradient.

5 An apparatus used for quantitative tests is shown schematically in Figure 2. The apparatus consisted of a cylindrical epoxy conductivity cell 25 of internal diameter about 20 mm, having three axially spaced annular carbon electrodes 26. The electrodes were connected to a constant
10 voltage supply so that the centre electrode was negatively charged and the other two were positively charged. Versaclean was poured into this cell and a constant voltage applied. A layer of oil 27 was observed to form at the surface of the mud 28 and an electro-deposit 29 collected on
15 the negative electrode. A barite layer 30 settled at the bottom of the cell. The oil is believed to rise to the surface owing to a weakening of the gel as fine particles migrated from the centre of the cell to form the deposit. The cell was weighed empty, and then after the treated
20 drilling fluid (effluante) was poured out. The increment of weight comprised the weight of the deposit and the residual fluid unremoved by gravity that adhered to the inside of the cell. The API rheological parameters PV and YP, and the API 100 PSI fluid loss, were measured for the effluante poured
25 from the cell.

The effect of voltage and time on the mass of the deposit is shown in Figure 3. Closed circles show the electrodeposit mass after 25 min. Open circles show the mass deposited after 40 minutes corrected to 25 min assuming the
30 electrodeposit was directly proportional to the time of voltage application. The collected data show that the mass deposited was proportional to voltage and time.

A variety of different oil based drilling fluids were then investigated with the epoxy cell method, in which a voltage of 200 V was applied for a duration of 25 minutes. These fluids were two different field samples of Versaclean (Versaclean 1 and Versaclean 2), and a further sample of Versaclean 2 which has been centrifuged at 3000 rpm for 20 mn to remove barite. Measurements of the electrical stability and density of the untreated muds and of PV and YP before and after treatment are shown in Table 1.

Table 1: Properties of field and laboratory OBMs

	API Electrical Stability (untreated) (V)	Density (untreated) (g/ml)	PV (untreated)	PV (treated)	YP (untreated)	YP (treated)
Versaclean 1	517	1.45	78	69	37	32
Versaclean 2	435	1.455	58	52	30	25
Versaclean 2 Barite-free	449	1.025	39	32.5	28	27.5

Thus the PV and YP of all the Versaclean OBMs were reduced by the treatment.

Figure 4 shows a graph of the mass of the electrodeposit against voltage for each of the OBMs, including the Versaport OBM. This shows that the electrodeposit mass depends on the density of the mud, suggesting that the fine particles attracted to the negative electrode tend to trap the barite. The graph also shows that high voltages do not necessarily provide a greater electrodeposit. For all the field muds the electrodeposit mass reached a maximum between 450 to 500 V. The collection process becomes less efficient as the applied voltage approached the breakdown voltage of the API Electrical Stability test (API 1988), possibly owing to a drop in the electric field experienced by the oil phase as chains of emulsion droplets begin to form prior to dielectric breakdown (Growcock et al. 1994).

Non-ohmicity and time-dependence

Using the apparatus of Figure 2 electrophoretic separation was performed on Versaclean OBM for various times and voltages and the current measured. Figure 5 shows a graph of current against voltage. The current was observed to increase with voltage in typical ohmic behaviour up to 200 V but at higher voltages there was a clear non-ohmic and time-dependent behaviour. This suggests a complex conduction mechanism which corresponds with the observation that as the applied voltage approaches the breakdown voltage progressively less deposit is collected on the negative electrode. These results again suggest that the electrodeposition process is more effective at voltages less than the breakdown voltage of the API Electrical Stability test (API 1988).

In tests on Versaclean, the total solids content by weight in the deposit was found to be about 64%wt while that of the mud was 57%wt, showing that the deposit solids were more concentrated than in the drilling fluid. Similarly, the electrodeposit yield stress was about five times that of the untreated mud, suggesting that the deposit had more fine clay particles than the mud.

Measurements of the concentration by weight of metal species in the deposit and mud were made using inductively-coupled plasma metal analysis, and the results are shown in Table 2.

Table 2: Elemental analysis of deposit and mud

	Al/Ba	Al/Cl	Al/C	Al/Ca	Ba/C
Mud	0.185	0.356	0.025	0.207	0.136
Deposit	0.21	0.487	0.034	0.208	0.16
Deposit/mud % increase	15%	37%	36%	0%	18%

Assuming the clay to be the only source of Al, the ratios of Al to Ba, Cl and C suggest that the deposit has gained

significantly in clay. The null change in Al/Ca suggests that some Ca may be bonded to the clay, and the 18% increase in the Ba/C ratio shows that there was less oil in the deposit.

5 *Effect of shear on field mud (Versaclean)*

The effect of shear on the electrodeposition process was investigated using a modified Chan 35TM oilfield rheometer in which the outside of the rotor was electrically-isolated from the rheometer body and acted as one electrode, while a brass
10 cup of inner diameter 57 mm was inserted into a heat cup to act as the rheometer stator and also the other
 (earthed/grounded) electrode. In this configuration the drilling fluid could be sheared in the gap between the rotor and stator and the deposit could be collected on the outside
15 of the rotor. The rotor gave a larger collection surface area than the annular electrode of the epoxy cell of Fig. 2, while allowing the mud to be sheared and/or heated simultaneously with the electric field applied.

Using the Chan rotor R1 outer diameter of 40.65 mm and a
20 brass cup inner diameter of 57.00 mm gave a laminar shear rate per unit RPM at the surface of the rotor of 0.43
 s⁻¹/RPM. The results are shown in Table 3. Some results are also plotted on Figure 6, which is a graph of deposit weight against rotor speed. Figure 6 demonstrates that the effect
25 of shear was to reduce the amount of deposit.

Table 3: Effect of shear, voltage, and time on electrodeposit mass for field Versaclean OBM

Rotor speed (RPM)	Applied voltage (V)	Treatment time (min)	Deposit weight (g)	PV post-treatment	YP post-treatment
0	0	0	-	58	30
200	0	25	-	52	27
200	0	100	-	45.5	30
0	40	250	32.7	43	23
0	400	40	41.60	30	11
0	400	25	35.72	37	16
20	400	25	27.8	36	26
100	400	25	22.29	45	15
200	400	25	16.72	48	18
200	400	40	19.59	40	18
200	400	60	23.29	41	7

These results, together with a range of tests on samples of used field Versaclean OBM and lab Versaport OBM may be summarized as follows:

- With no shear, the longer the exposure to the electrical field, the greater the amount of deposit and the lower PV and YP.
- The deposit weight increases with both time and voltage in both static and sheared tests. The very low voltage test over a long time (40V at 250 min) produced a similar deposit to 400 V at 25 min.
- PV and YP were reduced as the deposit increased.
- Elemental analysis after treatment of the Versaport mud indicated that the electro-deposit was enriched in Ba, Ca, Al, Na, Cl and depleted in organics (C, H, N) compared to the original mud. The reverse was found in the treated mud, confirming solids-removal from the fluid.
- Shear reduced the mass of electro-deposit (see Figure 6) and the effect of electro-treatment on the rheology. Sheared electro-deposits were also more fluid than static electro-deposits.

- Combinations of static and sheared periods of electro-treatment generally increased the electro-deposit. The order of imposition of electric field and shear appears to have an effect on rheology.

- 5 • Reversal of the field polarity causes the deposit to detach from the electrode and slump to the bottom.

Other variations altering the sequence of electrical treatment and shear in two stages were attempted and the results are shown in Table 4. The mud was treated first for 10 25 min with an applied voltage of 400 V with no shear. Then the treated system was placed under a shear of 200 rpm for 25 min. The amount of deposit formed was higher and PV and YP was generally lower than that when the mud was subjected to a simultaneous electric field and shear. Reversing the order 15 of this process resulted in a higher amount of material being deposited but also a higher PV and YP.

Table 4: Two phase test conditions and results of experiments investigating effect of a treatment combining shear and voltage on weight of deposit, PV and YP (Versaclean field- 20 OBM)

Rotor speed (RPM)		Applied voltage (V)		Time (mn)		Deposit weight (g)	PV (treated)	YP (treated)
Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2			
0	200	400	0	25	25	27.27	22	20
200	0	0	400	25	25	31.58	44	21
200	200	0	400	25	25	17.49	43	20

Effect of temperature on field mud (Versaclean)

Figure 7 is a graph of deposit weight against test temperature obtained by testing the Versaclean OBM in the modified Chan rheometer. The effect of increasing the 25 temperature, at a fixed voltage, was to usefully increase the weight of the deposit. Decreases in PV and YP, measured at

laboratory temperature after treatment, are also shown in the graph.

Continuous-flow and batch embodiments

The experiments described above show the utility of treating oil based drilling or completion fluids with an electric field. We now propose continuous-flow and batch embodiments that may be useful in full-scale or engineering applications. These serve to demonstrate the application of the invention but other examples are possible.

Figure 8 shows schematically a longitudinal section through a continuous-flow device for recycling used OBM. The drilling or completion fluid 1 enters an electrically-conductive and horizontal pipe 2, which bifurcates into pipe 3 and 4, each branch containing a valve 5 and 6. A series of annular electrodes 7 are held in pipe 2 and insulated from it by means of insulators 8. Electrical contact to each annular electrode is made via leads 9 and insulating bushes 10. Leads 11 and 12 respectively connect the electrodes and the pipe 2 to an electrical supply. In operation electrodeposit 13 forms on each of electrodes 7.

We have found (see above) that shear tends to reduce the efficiency of the deposition process. However, Figure 6 shows that at sufficiently low shear rates, the efficiency is largely undiminished. For example, Figure 6 shows that 10 RPM had little effect on the deposition rate. In our modified Chan 35 oilfield rheometer, 10 RPM corresponds to about 4.3 s^{-1} . For a pipe of diameter D , the relation between wall shear rate (WSR), volumetric flow rate (Q) and mean axial velocity (V) is $\text{WSR} = 16V/(3D) = 64Q/(3\pi D^3)$. This sets an upper limit on V and Q , in order that the deposition process is not unduly lessened. For example, for $D = 0.1 \text{ m}$

and $WSR = 4.3 \text{ s}^{-1}$, $V = 0.22 \text{ m s}^{-1}$, approximately, which corresponds to about 100 l min^{-1} .

The device operates as follows. Deposit is collected on electrodes 7 with valve 5 open and valve 6 closed. Pipe 3 then exudes a drilling fluid with less fine particles than entered via pipe 2. After sufficient time (to be found by experiment and corresponding to a lessening deposition rate as the deposit intrudes into the body of pipe 2) valve 5 is closed, valve 6 is simultaneously opened, and the voltage applied to form the deposit is reversed. This pushes deposit into the body of pipe 2, where its greater density than the surrounding fluid causes it to be preferentially collected by pipe 4 and led into a suitable collection vessel.

An alternative continuous-flow embodiment for such a device is shown in longitudinal section in Figure 9a and in transverse section in Figure 9b. In this case the drilling or completion fluid 1' enters a horizontal pipe 2' which is an electrical insulator. Pipes 3' and 4', with valves 5' and 6', resemble the bifurcation and valves of the device shown in Figure 8. Electrodes 7' and 7'' now run axially along pipe 2', and are connected to a voltage source via leads 11' and 12', such that the electro-deposit 13' collects along the lower electrode 7'' over a suitable time period and voltage, both to be determined by experiment. Pipe 3' then exudes a fluid with less fine particles than entered via pipe 2'. After sufficient deposit is collected, the flow is stopped, valves 5' and 6' are closed and opened, respectively, the voltage is reversed, and the flow re-started. The re-start flow rate should be large enough to quickly remove the deposit, but not so large as to remix it with the incoming fluid. The deposit then exudes via pipe 4' and led to a suitable collection vessel.

The above two examples are illustrative of a variety of possible deposit removal systems, which may also include scraper-type devices or similar apparatus.

5 While the invention has been described in conjunction with the exemplary embodiments described above, many equivalent modifications and variations will be apparent to those skilled in the art when given this disclosure. For example, in batch embodiments the electrodes may be set into a stirred or a static tank. Accordingly, the exemplary embodiments of
10 the invention set forth above are considered to be illustrative and not limiting. Various changes to the described embodiments may be made without departing from the spirit and scope of the invention.

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Claims

1. A method of removing particulate solids from an oil based drilling or completion fluid, comprising:

5 exposing the fluid to an electric field to electrically migrate particulate solids suspended therein, and
collecting the migrated particulate solids to remove them from the fluid.

2. A method according to claim 1, wherein the fluid comprises a water-in-oil emulsion, and the strength of the
10 electric field is lower than that required to coalesce the water droplets of the emulsion.

3. A method according to claim 1 or 2, wherein the strength of the electric field is less than 100,000 V/m.

4. A method according to any one of the previous claims,
15 wherein the strength of the electric field is controlled such that current and voltage remain proportional to each other.

5. A method according to any one of the previous claims, wherein the PV and/or YP of the fluid are reduced as a result of the collection of the particulate solids.

20 6. A method according to any one of the previous claims, wherein the fluid contains clay particles.

7. A method according to any one of the previous claims, wherein the fluid contains weighting agent particles.

8. A method according to any one of the previous claims,
25 wherein the particulate solids in the fluid occupy at least 5 vol. % of the total fluid.

9. A method according to any one of the previous claims, wherein the fluid is a shear-thinning fluid which forms a gel when quiescent.

10. A method according to any one of the previous claims, further comprising heating the fluid to enhance the collection of particulate solids.

11. A method of recycling an oil based drilling or completion fluid by performing the method of any one of the previous claims.

12. A method according to claim 11, including the step of using a centrifuge or hydrocyclone to remove other particulate solids from the fluid.

13. A method according to claim 1, including the step of using at least two electrodes to generate the electric field.

14. A method according to claim 1, including the step of using at least two electrodes to generate the electric field and a deposit removal system co-located with the electrodes.

15. A method according to claim 14, wherein deposit removal system is operated continuously or as a batch process.

16. An apparatus for removing particulate solids from an oil based drilling or completion fluid, comprising:

electrodes adapted to expose the fluid to an electric field to electrically migrate particulate solids suspended therein, and

a deposit removal system for collecting the migrated particulate solids to remove them from the fluid.

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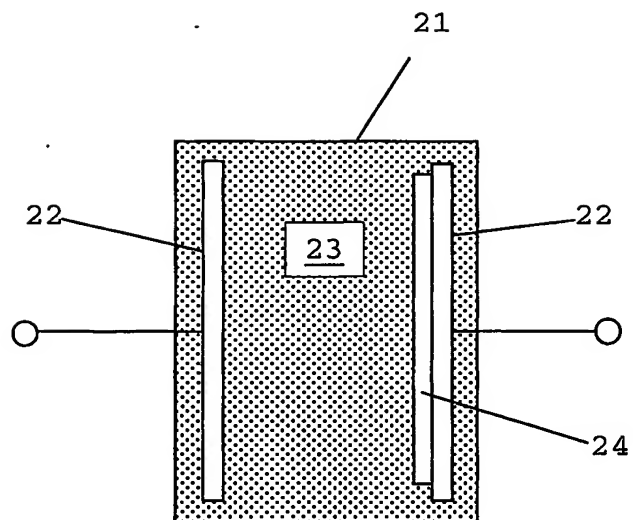


Figure 1

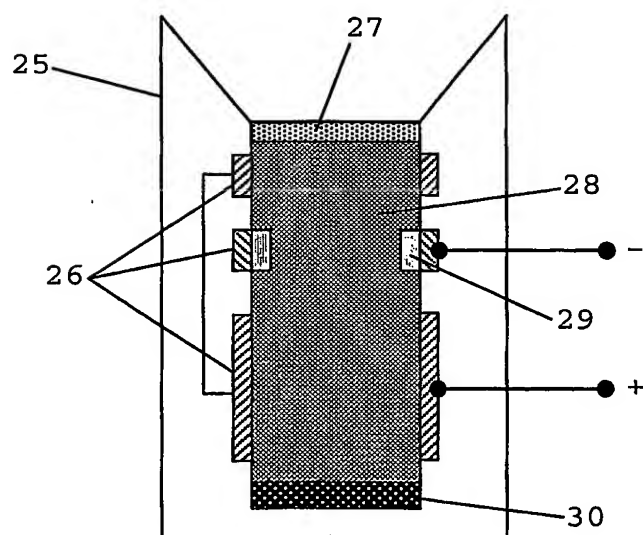


Figure 2

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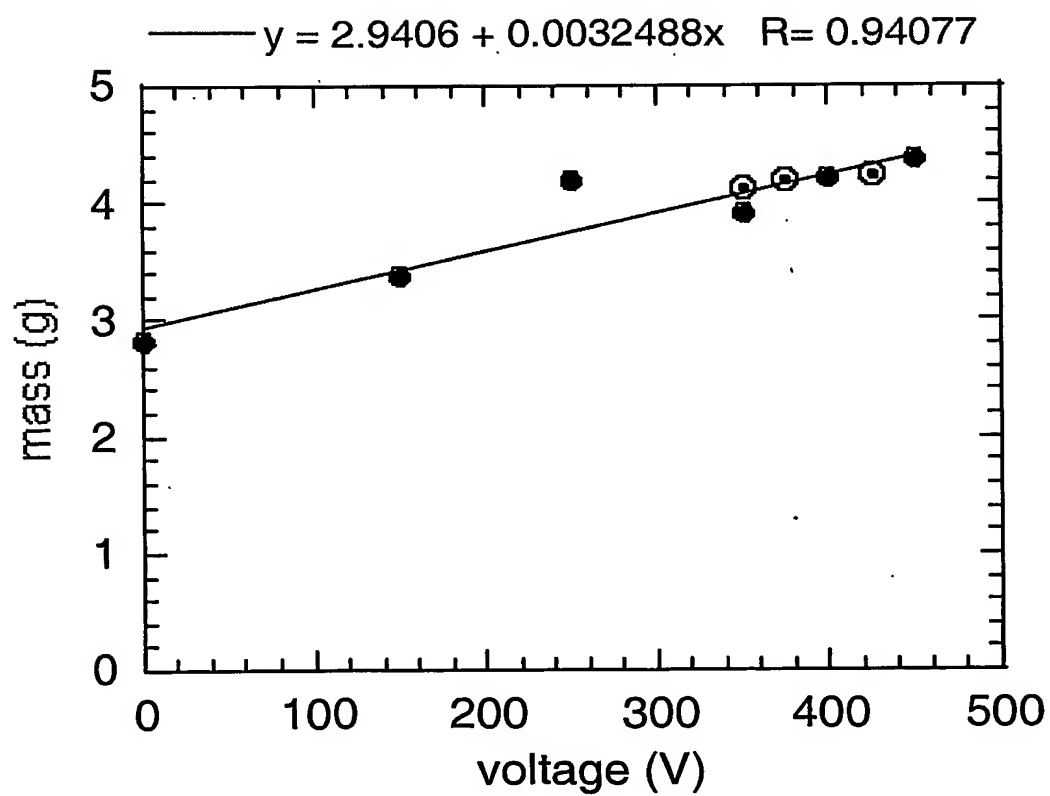


Figure 3

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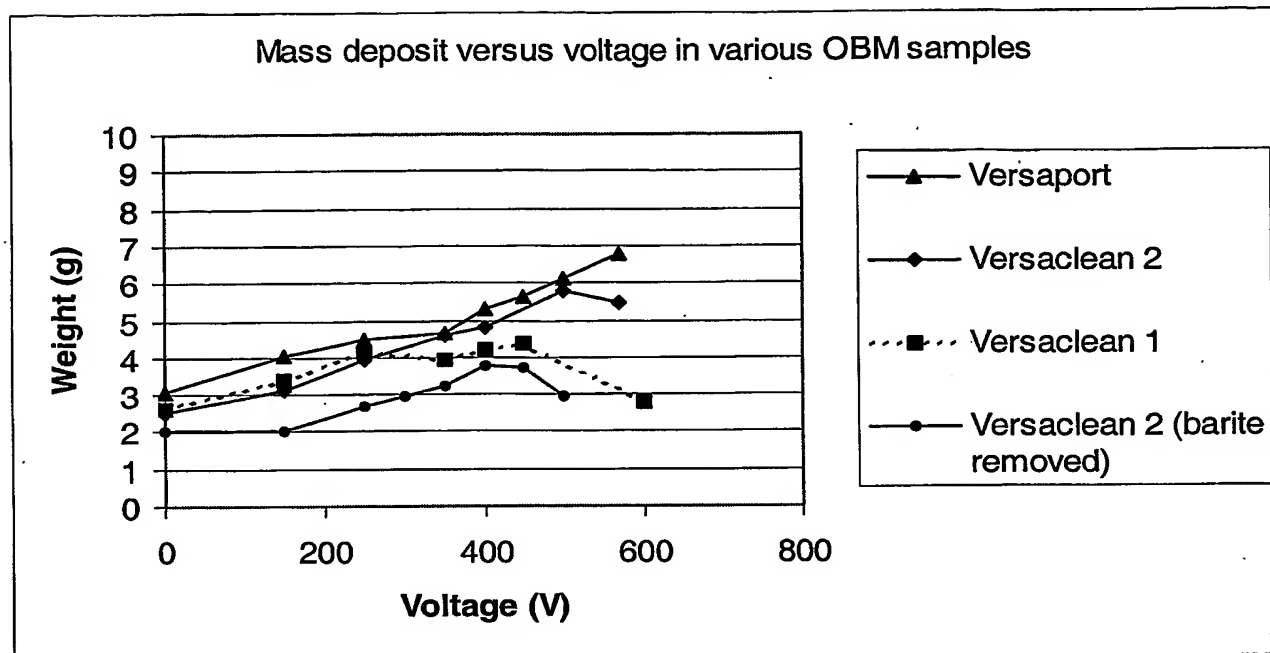


Figure 4

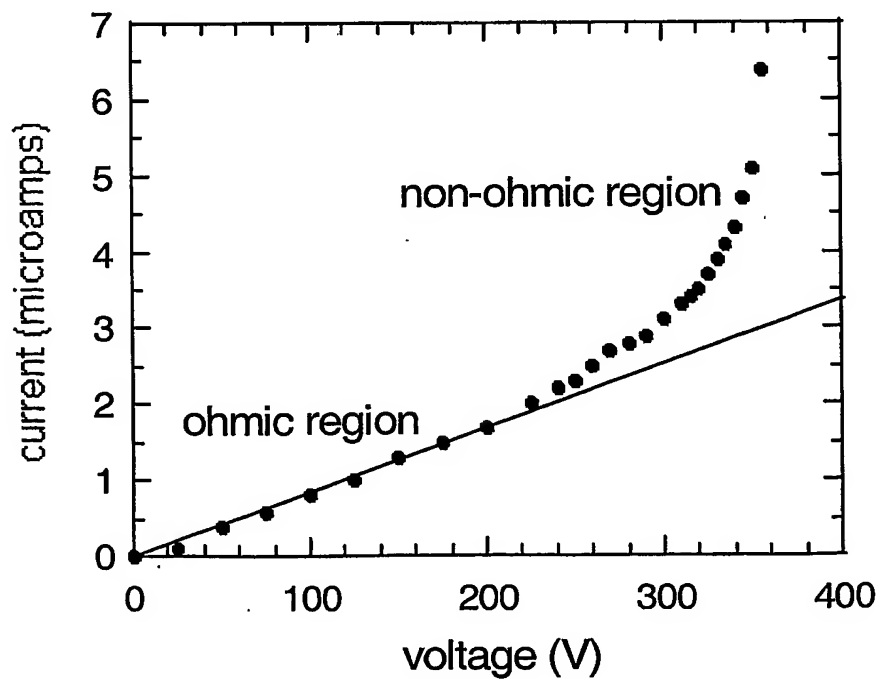


Figure 5

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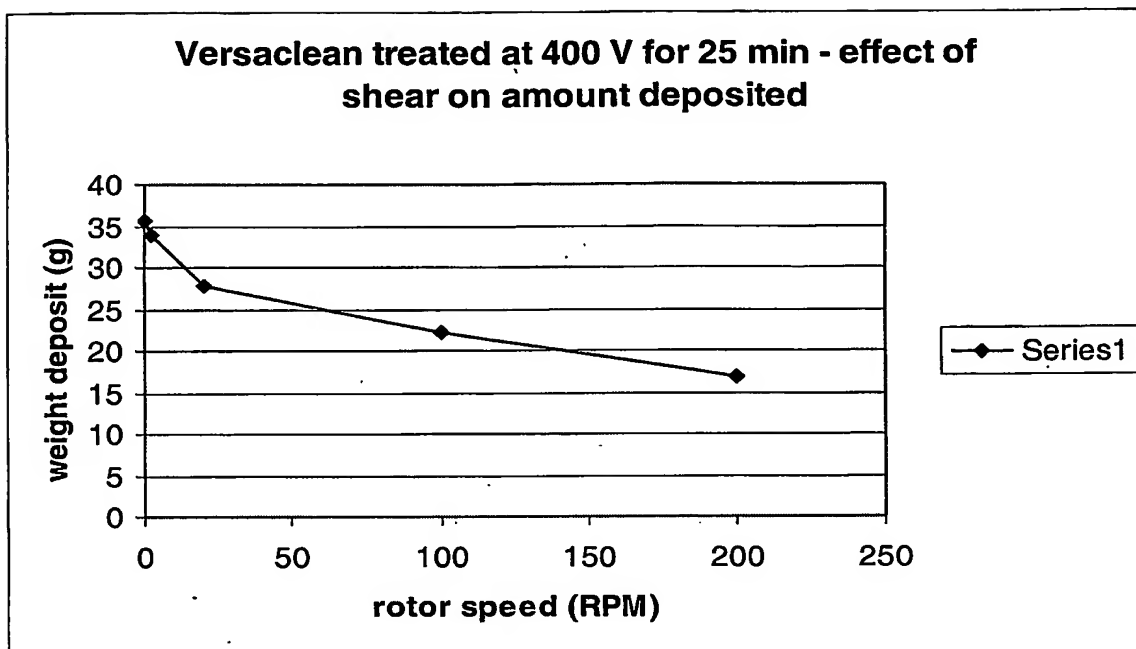


Figure 6

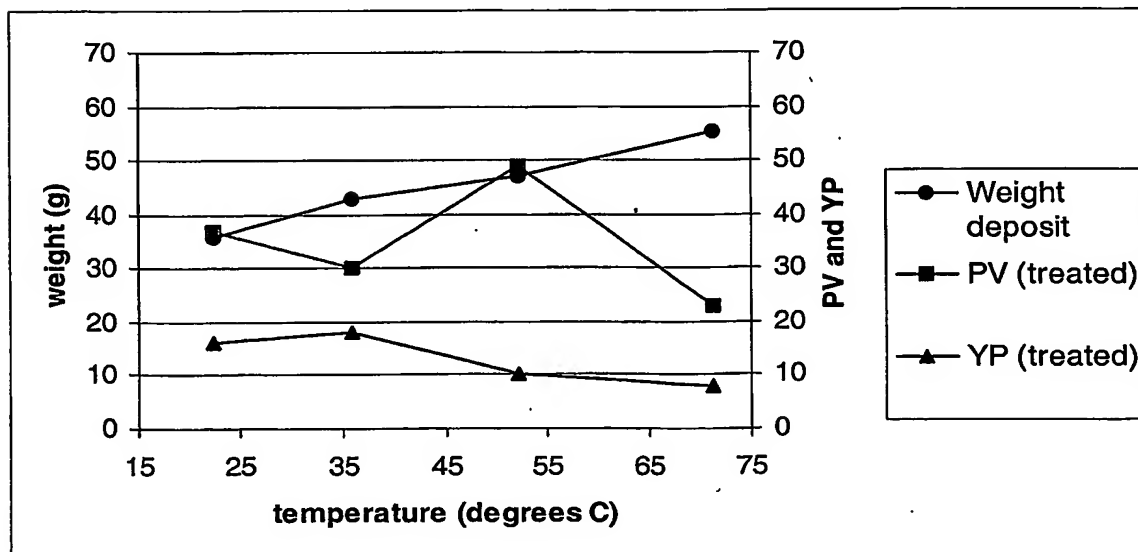


Figure 7

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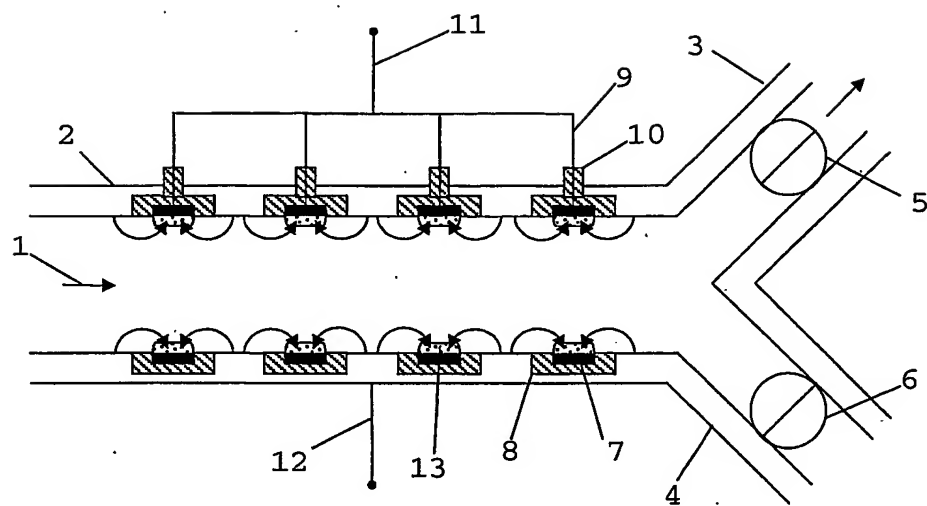


Figure 8

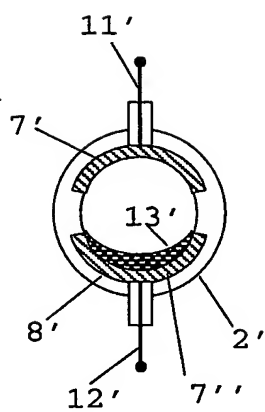


Figure 9(b)

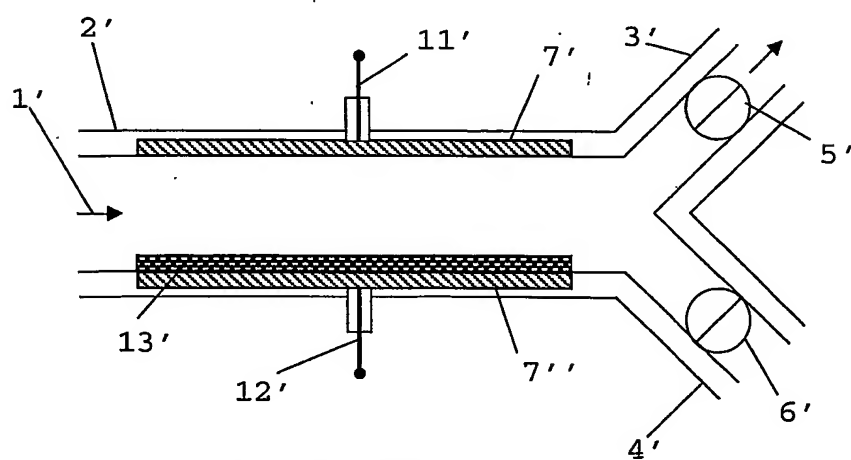


Figure 9(a)

INTERNATIONAL SEARCH REPORT

ational Application No

/GB2004/002863

A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 E21B21/06

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 E21B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3 928 158 A (FRITSCH G RAY ET AL) 23 December 1975 (1975-12-23) column 2, line 25 - line 62 column 5, line 29 - line 51 column 6, line 17 - line 41 claim 1; figure 1 The additional subject-matter of claims 4-5, 8, 9-12 does not appear to involve an inventive step when this document is considered alone.	1-5, 7-13,16
X	US 4 170 529 A (FREEMAN MARK P) 9 October 1979 (1979-10-09) column 8, line 47 - column 9, line 2; claim 1; figures 1-4 ----- -/-	1,6, 14-16



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

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Date of the actual completion of the international search

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Stroemmen, H.

INTERNATIONAL SEARCH REPORT

International Application No

/GB2004/002863

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3 799 857 A (FRANSE A) 26 March 1974 (1974-03-26) claim 1; figure 1 column 3, line 45 - column 4, line 53 -----	1,16
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(74) Agent: **MIRZA, Akram, Karim**; Intellectual Property Law Department, Schlumberger Cambridge Research Limited, High Cross, Madingley Road, Cambridge CB3 0EL (GB).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

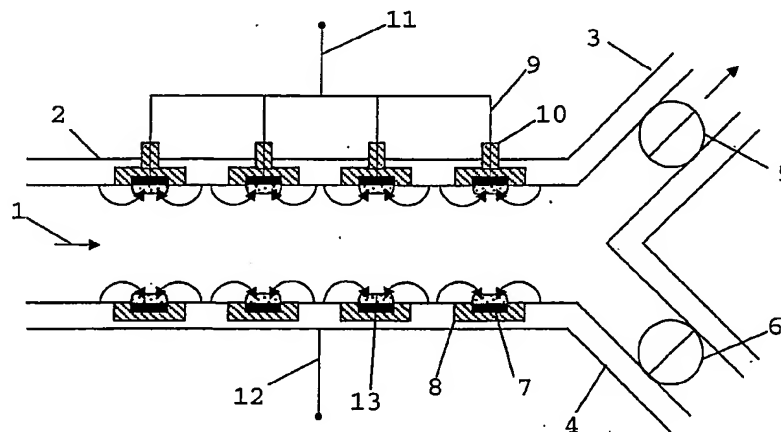
(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— with international search report

[Continued on next page]

(54) Title: ELECTRICAL TREATMENT FOR OIL BASED DRILLING OR COMPLETION FLUIDS



(57) Abstract: A method of removing particulate solids from an oil based drilling or completion fluid (1) is disclosed. The method involves exposing the fluid to an electric field to electrically migrate particulate solids suspended therein, and collecting the migrated particulate solids to remove them from the fluid.

WO 2005/017307 A1



For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

INTERNATIONAL SEARCH REPORT

International Application No

/GB2004/002863

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 3928158	A	23-12-1975	NONE
US 4170529	A	09-10-1979	US 4107026 A 15-08-1978
		AU 504869 B2 01-11-1979	
		AU 2554477 A 30-11-1978	
		BE 855796 A1 17-10-1977	
		BR 7703895 A 09-05-1978	
		CA 1084873 A1 02-09-1980	
		CS 209515 B2 31-12-1981	
		DE 2726604 A1 29-12-1977	
		FR 2354802 A1 13-01-1978	
		GB 1568286 A 29-05-1980	
		IN 155949 A1 30-03-1985	
		IT 1116640 B 10-02-1986	
		JP 1368488 C 11-03-1987	
		JP 52154183 A 21-12-1977	
		JP 61036968 B 21-08-1986	
		NL 7706125 A 20-12-1977	
		US 4207158 A 10-06-1980	
		US 4168222 A 18-09-1979	
		ZA 7703147 A 31-01-1979	
US 3799857	A	26-03-1974	NONE
US 4269681	A	26-05-1981	NONE
WO 9530726	A	16-11-1995	AU 694231 B2 16-07-1998
		AU 2585895 A 29-11-1995	
		CA 2190026 A1 16-11-1995	
		DE 69507468 D1 04-03-1999	
		DE 69507468 T2 02-09-1999	
		EP 0759059 A1 26-02-1997	
		NO 964737 A 08-11-1996	
		WO 9530726 A1 16-11-1995	

INTERNATIONAL SEARCH REPORT

International Application No
/GB2004/002863

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3 799 857 A (FRANSE A) 26 March 1974 (1974-03-26) claim 1; figure 1 column 3, line 45 - column 4, line 53 -----	1,16
X	US 4 269 681 A (WATSON FREDERICK D ET AL) 26 May 1981 (1981-05-26) claims 1,7; figure 1 -----	1,16
X	WO 95/30726 A (EXXON RESEARCH ENGINEERING CO) 16 November 1995 (1995-11-16) page 12, line 1 - line 19; claim 1; figure 2 -----	1,16

INTERNATIONAL SEARCH REPORT

International Application No
/GB2004/002863

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 E21B21/06

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 E21B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3 928 158 A (FRITSCH G RAY ET AL) 23 December 1975 (1975-12-23) column 2, line 25 - line 62 column 5, line 29 - line 51 column 6, line 17 - line 41 claim 1; figure 1 The additional subject-matter of claims 4-5, 8, 9-12 does not appear to involve an inventive step when this document is considered alone.	1-5, 7-13,16
X	US 4 170 529 A (FREEMAN MARK P) 9 October 1979 (1979-10-09) column 8, line 47 - column 9, line 2; claim 1; figures 1-4 ----- -/-	1,6, 14-16

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents:

- *A* document defining the general state of the art which is not considered to be of particular relevance
- *E* earlier document but published on or after the international filing date
- *L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- *O* document referring to an oral disclosure, use, exhibition or other means
- *P* document published prior to the international filing date but later than the priority date claimed

- *T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- *X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- *Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- *G* document member of the same patent family

Date of the actual completion of the international search

6 October 2004

Date of mailing of the international search report

13/10/2004

Name and mailing address of the ISA

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NL - 2280 HV Rijswijk
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Fax: (+31-70) 340-3016

Authorized officer

Stroemmen, H.

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference 57.0551 WO PCT	FOR FURTHER ACTION see Form PCT/ISA/220 as well as, where applicable, item 5 below.	
International application No. PCT/GB2004/002863	International filing date (day/month/year) 02/07/2004	(Earliest) Priority Date (day/month/year) 12/08/2003
Applicant M-I L.L.C.		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 5 sheets.

☒ It is also accompanied by a copy of each prior art document cited in this report.

1. Basis of the report

- a. With regard to the language, the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

☐ The international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

- b. ☐ With regard to any nucleotide and/or amino acid sequence disclosed in the international application, see Box No. I.

2. ☐ Certain claims were found unsearchable (See Box II).

3. ☐ Unity of invention is lacking (see Box III).

4. With regard to the title,

☒ the text is approved as submitted by the applicant.

☐ the text has been established by this Authority to read as follows:

5. With regard to the abstract,

☐ the text is approved as submitted by the applicant.

☒ the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box No. IV. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. With regards to the drawings,

- a. the figure of the drawings to be published with the abstract is Figure No. 8

☒ as suggested by the applicant.

☐ as selected by this Authority, because the applicant failed to suggest a figure.

☐ as selected by this Authority, because this figure better characterizes the invention.

- b. ☐ none of the figures is to be published with the abstract.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/GB2004/002863

Box No. IV Text of the abstract (Continuation of item 5 of the first sheet)

A method of removing particulate solids from an oil based drilling or completion fluid (1) is disclosed. The method involves exposing the fluid to an electric field to electrically migrate particulate solids suspended therein, and collecting the migrated particulate solids to remove them from the fluid.

INTERNATIONAL SEARCH REPORT

Intern. Application No

PCT/GB2004/002863

A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 E21B21/06

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 E21B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EP0-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3 928 158 A (FRITSCH G RAY ET AL) 23 December 1975 (1975-12-23) column 2, line 25 - line 62 column 5, line 29 - line 51 column 6, line 17 - line 41 claim 1; figure 1 The additional subject-matter of claims 4-5, 8, 9-12 does not appear to involve an inventive step when this document is considered alone.	1-5, 7-13,16
X	US 4 170 529 A (FREEMAN MARK P) 9 October 1979 (1979-10-09) column 8, line 47 - column 9, line 2; claim 1; figures 1-4 ----- -/-	1,6, 14-16

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents:

- *A* document defining the general state of the art which is not considered to be of particular relevance
- *E* earlier document but published on or after the international filing date
- *L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- *O* document referring to an oral disclosure, use, exhibition or other means
- *P* document published prior to the international filing date but later than the priority date claimed

- *T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- *X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- *Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- *&* document member of the same patent family

Date of the actual completion of the international search

6 October 2004

Date of mailing of the international search report

13/10/2004

Name and mailing address of the ISA

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NL - 2280 HV Rijswijk
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Fax: (+31-70) 340-3016

Authorized officer

Stroemmen, H.

INTERNATIONAL SEARCH REPORT

International Application No

PCT/GB2004/002863

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3 799 857 A (FRANSE A) 26 March 1974 (1974-03-26) claim 1; figure 1 column 3, line 45 - column 4, line 53 -----	1,16
X	US 4 269 681 A (WATSON FREDERICK D ET AL) 26 May 1981 (1981-05-26) claims 1,7; figure 1 -----	1,16
X	WO 95/30726 A (EXXON RESEARCH ENGINEERING CO) 16 November 1995 (1995-11-16) page 12, line 1 - line 19; claim 1; figure 2 -----	1,16

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/GB2004/002863

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
US 3928158	A	23-12-1975	NONE	
US 4170529	A	09-10-1979	US 4107026 A	15-08-1978
			AU 504869 B2	01-11-1979
			AU 2554477 A	30-11-1978
			BE 855796 A1	17-10-1977
			BR 7703895 A	09-05-1978
			CA 1084873 A1	02-09-1980
			CS 209515 B2	31-12-1981
			DE 2726604 A1	29-12-1977
			FR 2354802 A1	13-01-1978
			GB 1568286 A	29-05-1980
			IN 155949 A1	30-03-1985
			IT 1116640 B	10-02-1986
			JP 1368488 C	11-03-1987
			JP 52154183 A	21-12-1977
			JP 61036968 B	21-08-1986
			NL 7706125 A	20-12-1977
			US 4207158 A	10-06-1980
			US 4168222 A	18-09-1979
			ZA 7703147 A	31-01-1979
US 3799857	A	26-03-1974	NONE	
US 4269681	A	26-05-1981	NONE	
WO 9530726	A	16-11-1995	AU 694231 B2	16-07-1998
			AU 2585895 A	29-11-1995
			CA 2190026 A1	16-11-1995
			DE 69507468 D1	04-03-1999
			DE 69507468 T2	02-09-1999
			EP 0759059 A1	26-02-1997
			NO 964737 A	08-11-1996
			WO 9530726 A1	16-11-1995

PATENT COOPERATION TREATY

From the
INTERNATIONAL SEARCHING AUTHORITY

To:

see form PCT/ISA/220

PCT

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY (PCT Rule 43bis.1)

Date of mailing
(day/month/year) see form PCT/ISA/210 (second sheet)

Applicant's or agent's file reference
see form PCT/ISA/220

FOR FURTHER ACTION
See paragraph 2 below

International application No.
PCT/GB2004/002863

International filing date (day/month/year)
02.07.2004

Priority date (day/month/year)
12.08.2003

International Patent Classification (IPC) or both national classification and IPC
E21B21/06

Applicant
M-I L.L.C.

1. This opinion contains indications relating to the following items:

- ☒ Box No. I Basis of the opinion
- ☒ Box No. II Priority
- ☐ Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- ☐ Box No. IV Lack of unity of invention
- ☒ Box No. V Reasoned statement under Rule 43bis.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- ☐ Box No. VI Certain documents cited
- ☒ Box No. VII Certain defects in the international application
- ☐ Box No. VIII Certain observations on the international application

2. FURTHER ACTION

If a demand for international preliminary examination is made, this opinion will usually be considered to be a written opinion of the International Preliminary Examining Authority ("IPEA"). However, this does not apply where the applicant chooses an Authority other than this one to be the IPEA and the chosen IPEA has notified the International Bureau under Rule 66.1bis(b) that written opinions of this International Searching Authority will not be so considered.

If this opinion is, as provided above, considered to be a written opinion of the IPEA, the applicant is invited to submit to the IPEA a written reply together, where appropriate, with amendments, before the expiration of three months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later.

For further options, see Form PCT/ISA/220.

3. For further details, see notes to Form PCT/ISA/220.

Name and mailing address of the ISA:



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Authorized Officer

Stroemmen, H.

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**WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY**

International application No.
PCT/GB2004/002863

Box No. I Basis of the opinion

1. With regard to the **language**, this opinion has been established on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.
 - ☐ This opinion has been established on the basis of a translation from the original language into the following language , which is the language of a translation furnished for the purposes of international search (under Rules 12.3 and 23.1(b)).
2. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application and necessary to the claimed invention, this opinion has been established on the basis of:
 - a. type of material:
 - ☐ a sequence listing
 - ☐ table(s) related to the sequence listing
 - b. format of material:
 - ☐ in written format
 - ☐ in computer readable form
 - c. time of filing/furnishing:
 - ☐ contained in the international application as filed.
 - ☐ filed together with the international application in computer readable form.
 - ☐ furnished subsequently to this Authority for the purposes of search.
3. ☐ In addition, in the case that more than one version or copy of a sequence listing and/or table relating thereto has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.
4. Additional comments:

**WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY**

International application No.
PCT/GB2004/002863

Box No. II Priority

1. ☒ The following document has not been furnished:

- ☒ copy of the earlier application whose priority has been claimed (Rule 43*bis*.1 and 66.7(a)).
- ☐ translation of the earlier application whose priority has been claimed (Rule 43*bis*.1 and 66.7(b)).

Consequently it has not been possible to consider the validity of the priority claim. This opinion has nevertheless been established on the assumption that the relevant date is the claimed priority date.

2. ☐ This opinion has been established as if no priority had been claimed due to the fact that the priority claim has been found invalid (Rules 43*bis*.1 and 64.1). Thus for the purposes of this opinion, the international filing date indicated above is considered to be the relevant date.
3. Additional observations, if necessary:

Box No. V Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes: Claims	
	No: Claims	1-16
Inventive step (IS)	Yes: Claims	
	No: Claims	1-16
Industrial applicability (IA)	Yes: Claims	1-16
	No: Claims	

2. Citations and explanations

see separate sheet

Box No. VII Certain defects in the international application

The following defects in the form or contents of the international application have been noted:

see separate sheet

Re Item V.

- 1 The following documents are referred to in this communication:

D1 : US 3 928 158 A
D2 : US 4 170 529 A
D3 : US 3 799 857 A
D4 : US 4 269 681 A
D5 : WO 95/30726 A

- 2 Document D1 discloses (the references in parenthesis applying to this document):

A method and apparatus of removing particulate solids from an oil based drilling or completion fluid (see claim 1 and the figure), comprising: exposing the fluid (arrow at inlet port 16) to an electric field (col. 5, l. 29-51) to electrically migrate particulate solids suspended therein (see electrodes arranged in fig. 1), and collecting the migrated particulate solids to remove them from the fluid (claim 5).

2.1 INDEPENDENT CLAIM 1

As can be seen from the above, document D1 discloses in combination all the features defined in independent claim 1. Hence the subject-matter of this claim is not new (Article 33(2) PCT).

2.2 INDEPENDENT CLAIM 16

As can be seen from the above, document D1 discloses in combination all the features defined in independent claim 16. Hence the subject-matter of this claim is not new (Article 33(2) PCT).

- 3 Likewise, document D2 discloses (the references in parenthesis applying to this document) all the method steps and features of independent claims 1 and 16, respectively (see claim 1).

3.1 INDEPENDENT CLAIM 1

As can be seen from the above, document D2 discloses in combination all the features defined in independent claim 1. Hence the subject-matter of this claim is not new (Article 33(2) PCT).

3.2 INDEPENDENT CLAIM 16

As can be seen from the above, document D2 discloses in combination all the features defined in independent claim 16. Hence the subject-matter of this claim is not new (Article 33(2) PCT).

- 4 Document D3 discloses (the references in parenthesis applying to this document) substantially the same subject-matter as is the case of D1. The disclosure of D3 however is focused more on the migration and removal steps and means (see claim, paragraphs (d) and (e)).

4.1 INDEPENDENT CLAIM 1

As can be seen from the above, document D3 discloses in combination all the features defined in independent claim 1. Hence the subject-matter of this claim is not new (Article 33(2) PCT).

4.2 INDEPENDENT CLAIM 16

As can be seen from the above, document D3 discloses in combination all the features defined in independent claim 16. Hence the subject-matter of this claim is not new (Article 33(2) PCT).

5 DEPENDENT CLAIMS 2-15

Dependent claims 2-15 do not contain any features which, in combination with the features of any claim to which they refer, meet the requirements of the PCT in respect of novelty (Article 33(2) PCT).

Re Item VII.

- The terms "PV" and "YP" used in claim 5 has no well-recognised meaning and leaves the reader in doubt as to the meaning of the technical features to which they refer, thereby rendering the definition of the subject-matter of said claim unclear, Article 6 PCT.
- The features of the claims are not provided with reference signs placed in parentheses (Rule 6.2(b) PCT).
- The independent claims are not in the two-part form in accordance with Rule 6.3(b) PCT, which in the present case would be appropriate, with those features known in combination from the most relevant prior art being placed in

**WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING
AUTHORITY (SEPARATE SHEET)**

International application No.

PCT/GB2004/002863

the preamble (Rule 6.3(b)(I) PCT) and with the remaining features being included in the characterising part (Rule 6.3(b)(ii) PCT).

- The vague and imprecise statement in the description on page 18, "... spirit and scope of the invention ..." implies that the subject-matter for which protection is sought may be different to that defined by the claims, thereby resulting in lack of clarity (Article 6 PCT) when used to interpret them.
- Contrary to the requirements of Rule 5.1(a)(ii) PCT, the relevant background art disclosed in the documents D1-D5 is not mentioned in the description, nor are these documents identified therein.